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The 17th International CDIO Conference

Proceedings – Full Papers

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Editorial

The Annual International Conference is the key event for the CDIO community where CDIO practitioners from all over the world come together, share knowledge and promote the advancement of the practice of the CDIO framework for producing the next generation of engineers. The last event in 2020 was organized by Chulalongkorn University and Rajamangala University of Technology Thanyaburi and was planned to take place in Bangkok, Thailand. However, due to the pandemic situation, the conference was rearranged as an online conference hosted by Chalmers University of Technology, Sweden. The organizers from CDIO Thailand would like to thank Professor Johan Malmqvist and the CDIO office for facilitating the (online) sharing and social gathering to benefit the CDIO community even with such short notice.

For the present 17th International CDIO conference, the organizers readily realized that the event is to be held under the new normal circumstances. The local organizers, from the outset, intended to offer a satisfying online conference experience and a paper review with high quality. With as strong as ever support from our international program committee, we believed we had delivered on our intentions, as you can attest from the conference proceeding and the experience within the conference.

The conference covers three types of contributions; full papers; project in progress papers, and activities, allowing participants with different depth of expertise from different technological disciplines to share and learn under a common language of the CDIO syllabus and 12 standards. All contributions passed a complete single-blind peer-review process to ensure scholarly standards. From the initial 139 submitted contributions from 23 countries, 108 manuscripts arrived to go through the peer-review process participated by 92 members of the 2021 International Program Committee. The constructive remarks and numerous encouragements from reviewers to authors and even the organizing committees in this tough time of global pandemic served as a reminder of strong partnership within the CDIO community. We cannot be thankful enough for those who supported the rigorous standard of the review process.

The theme of this year was Reimagining Engineering Education in the New Normal. Education is as vital as ever as engines of economic development, as discussed in a roundtable session. From a keynote presentation and roundtable sessions, the participants were presented with pragmatic and systematic ways to transform the University context to address more effectively the societal need in the new normal trailed after the pandemic event. After all, the reimagining also comes down to educators/academics to come together as a community being bounded to a common language via the 12 Standards; keep improving and innovating and being agile as discussed in a keynote presentation, full papers and roundtable sessions during the event. Reimagining is not limited to universities and academics. The CDIO framework itself is continually rethought, as presented in an Advanced in CDIO paper. As a result of collaborative efforts and multiple reviews, Optional Standards was presented in a roundtable session.

This publication includes 66 full paper contributions, among which 49 are in the CDIO Implementation section, 6 are Advances in CDIO section, and 12 in Engineering Education Research section. During the event, participants can also learn about 12 Projects in Progress contributions documenting current developments or initiatives worth sharing yet had not reached archival capacity at the time of writing. In addition to individual contributions from authors, the Annual International Conference provided a range of activities to cater to social gathering opportunities and collaborative contributions in Workshops, Roundtable Discussions and Working Groups. Participants are encouraged to join in these activities to expand their view and experience and make the collaborative contributions even more robust for the CDIO community.

The pandemic may have disconnected us physically. Nevertheless, we are ever more connected via CDIO activities!

Bangkok, June 21, 2021

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DEVELOPMENT OF STUDENT SUSTAINABILITY AWARENESS, ATTITUDES AND ACTIONS

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ABSTRACT

Research on sustainability in Higher Education lacks the focus on measuring the differences in knowledge, attitudes and actions of students before and after being exposed to the 17 Sustainable Development Goals (SDGs), especially within a West-Asian context. The 17 SDGs and their learning objectives, developed by the UNESCO (2017), represent the framework of this study. For each of the SDGs, a relevant learning objective has been selected for measuring the awareness, attitude and action of students working on an engineering design/build project in teams. The learning objective of each SDG has been selected based on relevance for the given context. Students participated in a questionnaire survey to evaluate their awareness, attitude and action related to the SDGs on a 4-point response scale. This has been done twice, before and after being exposed to a design/build project using a Conceive-Design-Implement-Operate (CDIO) framework. Descriptive statistics as well as inferential statistics have been carried out in order to analyze the impact of the project on students' perspectives and illustrate the extent of the influence. Some SDGs were more affected by the project scenario than others. Scaffolding engineering students' learning of the SDGs by personal reflection ensured that no goal is excluded from the learning process. The results show that students' learning needs to be supported by reflection on these goals in order to avoid confining the learning process to SDGs that are developed more intensively by the project scenario. It is recommended to do future studies using an experimental/control group design in order to differentiate learning supported by reflection versus project scenario. The findings confirm the approach of including real life sustainability issues in the project scenario. This study is part of an ongoing research effort related to sustainability and engineering education in the region of the Gulf Cooperation Council (GCC).

KEYWORDS

Sustainability, Sustainable Development Goals, Knowledge, Awareness, Action, Standards: 4, 5, 8

INTRODUCTION AND BACKGROUND

Education has always been a longstanding solution for spreading peace and solving social challenges on a local and global scale. Educating for peace known as "peace education" aims to foster the necessary knowledge, skills and attitudes that cultivate a culture of peace and a prosperous society (United Nations Educational, Scientific and Cultural Organization, 2008). Peace education should be integrated and mainstreamed throughout any educational experience provided in the educational institution (Fountain, 1999). Engineering is a profession that is central to the resource consumption and continuous development (Huntzinger *et al.*, 2007). Future engineers should gain the sense of responsibility and carefulness towards solving issues and creating a better world. Therefore, it is the duty of higher education institutions to enable students to participate in the solutions necessary for the encountered challenges (Svanström *et al.*, 2008). The United Nations developed the Sustainable Development Goals (SDGs) with the aim of protecting the planet and creating a peaceful, prosperous and sustainable environment for people to enjoy. Incorporating these goals in engineering curricula widens the horizon of future engineers through letting them think about the local and global challenges and the possible solutions that can be used (Gereluk, 2012).

The United Nations Sustainable Development Goals (SDGs)

Never before has humanity faced an enormous amount of challenges as we encounter today (Svanström *et al.*, 2008). In 2015, 17 SDGs were formally adopted at the United Nations (UN) Sustainable Development Summit. One of the main aims of the UN is to achieve these SDGs by 2030 and thus secure a more sustainable future for all. SDGs seek to strengthen universal peace and provide a common vision for peaceful and prosperous societies. Sustainable development acts as a blueprint to secure the needs of the present without compromising the ability to meet the needs of the future (Boluk *et al.*, 2019). Integrating sustainability in education is a recent trend amongst higher education institutions (Shephard & Furnari, 2013). Promoting quality education is essential for improving people's lives and taking sustainable development one step forward (UNESCO, 2017).

The SDGs can serve the purpose of an overarching framework to systematically integrate the necessary knowledge, skills and values of peace education in addition to introducing future engineers to the concept of sustainable development. The 17 SDGs developed by the UNESCO (2017) are summarized below:

1. *No Poverty* (SDG 1) focuses on annihilating extreme poverty for all people everywhere (currently measured as people living on less than $1.25/day and access to affordable housing for all people).
2. *Zero Hunger* (SDG 2) focuses on problems related to limiting hunger and increasing sustainable agriculture and proper nutrition.
3. *Good Health and Well-being* (SDG 3) focuses on creating a healthy indoor and outdoor environment in addition to the utilization of sustainable and environment friendly building materials.
4. *Quality Education* (SDG 4) focuses on assuring life-long learning opportunities for all people and facilitating high-quality education for a sustainable built environment.
5. *Gender Equality* (SDG 5) focuses on fighting all forms of gender discrimination and violence in addition to eliminating the causes of gender inequality.
6. *Clean Water and Sanitation* (SDG 6) focuses on promoting waste water treatment and recycling in addition to increasing efficiency of water consumption in building construction and building material manufacturing.
7. *Affordable and Clean Energy* (SDG 7) focuses on increasing the investments in renewable energy and enhancing energy efficiency in buildings.
8. *Decent Work and Economic Growth* (SDG 8) focuses on increasing job creation through the building sector, cultivating innovation and providing a safe working environment.

9. *Industries, Innovation and Infrastructure* (SDG 9) focuses on developing reliable, sustainable and resilient infrastructure. It also covers increasing the usage of clean technologies in buildings and infrastructure.
10. *Reduce Inequalities* (SDG 10) generally focuses on inequality and discrimination within the society and especially against minority groups within a nation.
11. *Sustainable Cities and Communities* (SDG 11) focuses on providing a safe, affordable and accessible transport within cities and districts in addition to facilitating access to green spaces in cities.
12. *Responsible Consumption and Production* (SDG 12) promotes recycling in new building construction and renovation. It also endorses sustainability-oriented procurement practices for new construction and renovation.
13. *Climate Action* (SDG 13) focuses on climate change mitigation and adaptation in the built environment in addition to enhancing the resilience of the built environment towards natural disasters.
14. *Life Below Water* (SDG 14) focuses on ecology, ecosystems, how the current climate change is influencing these aspects and potentially minimizing these effects.
15. *Life on Land* (SDG 15) focuses on reducing the degradation of natural habitats and loss of biodiversity.
16. *Peace, Justice and Strong Institutions* (SDG 16) focuses on the social justice, inclusion and peace in nations and the law enforcement of these aspects.
17. *Partnerships for the Goals* (SDG 17) focuses on building long-term partnership between organizations and governments that would nurture financing for sustainable development, trade policies and the interconnectedness of different countries and populations.

Annan-Diab & Molinari (2017) followed the six principles of PRME (Purpose, Values, Method, Research, Partnerships and Dialogue) as a framework to integrate the sustainable development into a higher education curriculum. They recognized how this integration positively influenced the knowledge and awareness of students towards sustainable development. Similarly, Jain *et al*. (2013) previewed how the sustainable development concepts were embedded in higher education through various educational methods that also foster interdisciplinarity teamwork and role playing. Willats *et al.* (2018) emphasized the importance of integrating SDGs in the higher education institution curriculum through focusing on the different facets of sustainable development and moving away from the idea that sustainability is exclusively an environmental issue. They described how the integration was done in a holistic manner throughout a range of courses in the curriculum, rather than focusing on one course only, in order to cover the knowledge requirements and complexity of sustainable development. Looking into the literature, there is a general focus on the knowledge related to SDGs rather than the attitudes to be embedded in the students' behavior and actions to be taken towards the matter of sustainability.

PURPOSE

The purpose of this study is to identify the development of knowledge, attitude and action related to the 17 SDGs among engineering students of a private college in the GCC (Gulf Cooperation Council) region, during a design build project carried out within a CDIO framework. Although, only a few SDGs (3, 4, and 7) are directly related to this design build project, all 17 SDGs have been discussed with all students during the project. The results allow a comparison between students' perception before project commencement and after project completion. Furthermore, the difference between knowledge, attitude and action are analyzed.

METHODOLOGY

The framework for this study is reflected by the 17 SDGs developed by the UNESCO (2017). Following the approach of Sunthonkanokpong and Murphy (2019), one learning objective has been selected based on the five learning objectives per SDG provided by the UNESCO (2017) for each: knowledge, attitude and action. Discussions with students were conducted to ensure that the questionnaire's length is not overwhelming, and a total of 51 (3 × 17) items were included accordingly. During a focus group meeting of four faculty members, it was ensured that the selected learning objectives were relevant for the given context. In order to evaluate students' perception of knowledge, attitude and action related to the 17 SDGs, one questionnaire-based survey has been carried out before commencing the design build project (in the following called pre-test), and a second survey has been carried out after completing the project (in the following called post-test). Following the recommendation of Garland (1991, p.70), a 4-point response scale was chosen in order to avoid a midpoint of the instrument scale (i.e. uncertain or unsure), which could cause a social desirability bias among respondents. All 17 questionnaire statements related to knowledge begin with "My knowledge of…", the statements related to attitude begin with "I feel…" and the statements related to action begin with "I will…". The latter set of statements was introduced with "If I run my own engineering company,…". An example of statements for the *knowledge*, *attitude* and *action* section is shown for SDG 1 in Table 1.

Table 1. Example of Questionnaire Statements Related to SDG 1

Questionnaire section	Question [answer scale]
Knowledge	My knowledge of the consequences of poverty for poor individuals and society is… [very low, low, high, very high]
Attitude	I feel empathy for the people in poor situations. [strongly disagree, disagree, agree, strongly agree]
Action	I will provide some practical relief to people in a poor country and encourage my staff to be involved too. [No, unlikely, likely, yes]

The project brief of the design build project included the following information, and students had six weeks to work on the project. Furthermore, students were required to reflect each week on two to three SDGs, i.e. they were asked to answer the "What? So what? and What now? questions". This approach ensured that students interacted also with SDGs that were not directly related to the design build project.

Introduction

In factories and workshops of many parts of the world only standard exhaust fans are used for ventilation of the workplace. With increasing work activities and operation of equipment, the ventilation is insufficient and poses a risk for the health of the employees working in such an environment. Many business owners are not willing to increase wall openings and to procure and install larger exhaust fans, but they might consider exchanging existing blades with more efficient blades.

Project Scope

The International Health Organization (client, represented by your professor) has approached your interdisciplinary engineering design team to investigate if existing standard designs of exhaust fan blades (also called ventilation fan blades) can be optimized regarding weight (i.e. material consumption) and efficiency (i.e. ventilation capacity). The International Health Organization is interested in innovative design solutions and a physical model that reflects the shape of the exhaust fan blades and spinner.

The following requirements have to be met:

1) Research existing blade designs and efficiencies.
2) Research existing building codes and regulations regarding ventilation of workplaces.
3) Identify improvement potential of blades and spinner (e.g. shape, number of blades, etc.)
4) Design improved blades / spinner for a circular body (housing) and 200mm diameter sweep area.
5) Calculate the possible ventilation capacity based on realistic assumptions and compare with existing standards for exhaust fans.
6) Estimate the manufacturing cost of blades and spinner.
7) Estimate the financial consequences for business owners (e.g. electricity consumption, impact on work productivity, etc.)
8) Each team needs to 3-D-print a physical model of their blades and spinner using a scale of 1:2.
9) Each team member needs to show relevant sketches, sources and calculations in their Workbook. Excel is to be used for repetitive calculations.
10) Each team has to apply professional project management techniques.

For the descriptive statistics, Mean, Median and Standard Deviation have been computed, and for the significance testing a *t*-test for two samples has been applied since the number of students of the pre-test was not identical with the number of students of the post-test. Results of *t*-tests have been shown to be fairly robust against violating the assumption of a normal distribution, but they are strongly influenced by outliers (Pfahl *et al.,* 2004). Therefore, the existence of outliers has been analyzed, and it was found that all scores of the two tests are within +/- 2 standard deviations around the mean score.
Results of the data analysis are presented in the following section, before completing the study with a discussion section and conclusions.

RESULTS

The results of the descriptive statistics are shown for the pre-test and post-test in Table 2. For the pre-test, the highest Mean was found for SDG 4 of the *knowledge* section, SDG 2 of the *attitude* section and SDG 11 of the *action* section; whereas the lowest Mean was identified for SDG 9 of the *knowledge* and the *action* section and for SDG 15 of the *attitude* section. Regarding the post-test, the highest Mean was found for SDG 6 of the *knowledge* section, SDG 17 of the *attitude* section and SDG 14 of the *action* section; whereas the lowest Mean was found for SDG 17 of the *knowledge* section, SDG 15 of the *attitude* section and SDG 9 of the *action* section.

Table 2. Descriptive Statistics Results for Pre-test and Post-test (Increased Mean are Bold)

SDG	Pre-test / Post-test	Knowledge			Attitude			Action		
		Mean	Median	Standard Deviation	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
Poverty	Pre-test	2.76	3	0.64	3.52	4	0.65	3.42	3	0.66
	Post-test	**2.97**	3	0.72	3.51	4	0.64	3.31	3	0.71
Hunger	Pre-test	2.75	3	0.75	3.79	4	0.52	3.54	4	0.69
	Post-test	**2.93**	3	0.75	3.59	4	0.53	3.38	3	0.62
Health	Pre-test	3.27	3	0.64	3.65	4	0.54	3.20	3	0.81
	Post-test	**3.29**	3	0.70	3.57	4	0.58	**3.30**	3	0.58
Education	Pre-test	3.38	3	0.60	3.60	4	0.59	3.40	3	0.67
	Post-test	3.34	3	0.60	3.57	4	0.52	3.40	3	0.59
Gender	Pre-test	3.07	3	0.71	3.33	4	0.85	3.58	4	0.69
	Post-test	**3.22**	3	0.74	**3.45**	3	0.63	3.56	4	0.68
Water & Sanitation	Pre-test	3.18	3	0.74	3.40	3	0.65	3.43	4	0.67
	Post-test	**3.35**	3	0.78	**3.49**	4	0.62	3.40	3	0.68
Energy	Pre-test	2.90	3	0.80	3.42	3	0.59	3.30	3	0.75
	Post-test	**3.07**	3	0.94	**3.44**	3	0.70	**3.38**	3	0.71
Economy	Pre-test	2.43	2	0.81	3.51	4	0.66	3.63	4	0.60
	Post-test	**2.89**	3	1.03	**3.52**	3	0.72	3.54	4	0.73
Industry	Pre-test	2.29	2	0.76	3.23	3	0.65	2.94	3	0.83
	Post-test	**2.85**	3	1.08	**3.35**	3	0.79	**3.23**	3	1.01
Inequalities	Pre-test	2.91	3	0.75	3.57	4	0.69	3.27	3	0.70
	Post-test	**3.02**	3	1.08	3.57	4	0.88	**3.41**	3	0.89
Cities & Communities	Pre-test	3.14	3	0.67	3.45	4	0.63	3.73	4	0.51
	Post-test	**3.24**	3	1.12	**3.57**	4	0.96	3.65	4	0.94
Production & Consumption	Pre-test	3.02	3	0.75	3.33	3	0.64	3.52	4	0.61
	Post-test	**3.12**	3	1.21	**3.52**	3	1.04	**3.56**	4	1.07
Climate	Pre-test	3.07	3	0.67	3.41	3	0.62	3.06	3	0.93
	Post-test	**3.18**	3	1.30	**3.51**	3	1.13	**3.36**	3	1.23
Water Life	Pre-test	2.88	3	0.88	3.38	3	0.65	3.57	4	0.66
	Post-test	**3.15**	3	1.39	**3.44**	3	1.27	**3.63**	4	1.26
Land Life	Pre-test	2.45	2	0.84	3.06	3	0.84	3.18	3	0.74
	Post-test	**3.08**	3	1.51	**3.34**	3	1.41	**3.42**	3	1.40
Peace	Pre-test	2.78	3	0.93	3.63	4	0.60	3.30	3	0.72
	Post-test	**3.15**	3	1.57	3.62	3	1.40	**3.57**	3	1.44
Partnership	Pre-test	2.56	3	0.85	3.50	4	0.58	2.97	3	0.82
	Post-test	**2.84**	3	1.75	**3.63**	4	1.52	**3.46**	3	1.61

Results of the *t*-test are shown in Table 3. For the *knowledge* section, six SDGs (i.e. SDGs 1, 2, 8, 9, 15, and 16) show a statistically significant higher Mean (at alpha = 0.05) for the post-test; whereas results of two SDGs (i.e. SDG 4 and SDG 13) do not confirm the expected direction of the effect.

For the *attitude* section, no SDG shows a statistically significant higher Mean (at alpha = 0.05) for the post-test; whereas results of ten SDGs (i.e. SDGs 2, 3, 4, 7, 8, 10, 13, 14, 16, and 17) do not confirm the expected direction of the effect.

For the action section, two SDGs show a statistically significant higher Mean (at alpha = 0.05) for the post-test (i.e. SDG 9 and SDG 17); whereas results of nine SDGs (i.e. SDGs 1, 2, 4, 5, 6, 8, 11, 12 and 14) do not confirm the expected direction of the effect. Figures 1 to 3 show the difference in means related to the students' knowledge, attitude and action during the pre-test and post-test.

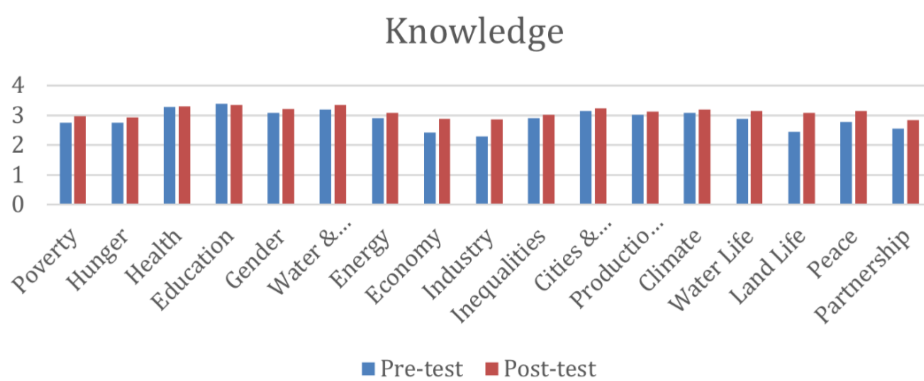

Figure 1. Mean of pre-test and post-test results of students' knowledge

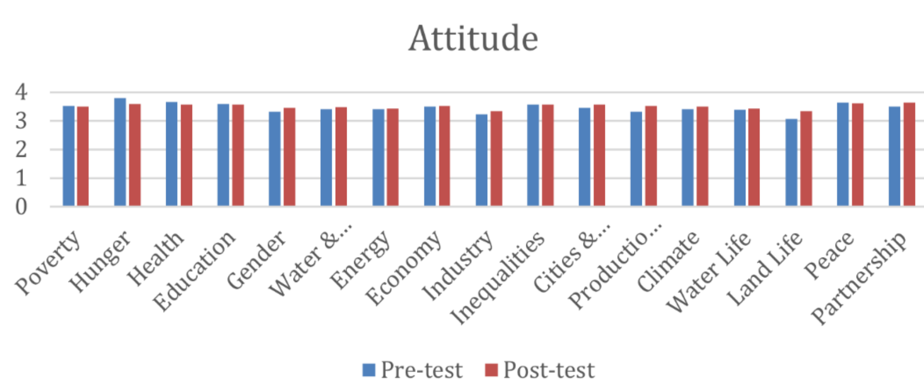

Figure 2. Mean of pre-test and post-test results of students' attitude

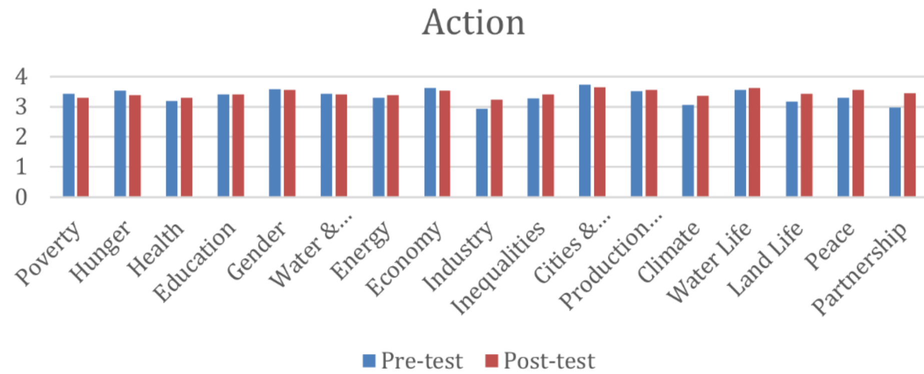

Figure 3. Mean of pre-test and post-test results of students' action

Table 3. Results of the *t*-test (Knowledge, Attitude, Action)

SDG	Knowledge				Attitude				Action			
	Degrees of freedom	t-Value	p-Value	$t\ Crit_{0.95}$	Degrees of freedom	t-Value	p-Value	$t\ Crit_{0.95}$	Degrees of freedom	t-Value	p-Value	$t\ Crit_{0.95}$
Poverty	180	2.320	0.011	1.653	184	0.138	0.445	1.653	183	-0.854	0.197	1.653
Hunger	183	1.757	0.040	1.653	184	-2.381	0.009	1.653	183	-1.475	0.071	1.653
Health	179	0.182	0.428	1.653	181	-0.825	0.205	1.653	173	0.983	0.164	1.654
Education	183	-0.472	0.319	1.653	183	-0.461	0.323	1.653	183	-0.075	0.470	1.653
Gender	183	1.206	0.115	1.653	173	0.918	0.180	1.654	184	-0.389	0.349	1.653
Water & Sanitation	183	1.345	0.090	1.653	183	0.790	0.215	1.653	184	-0.632	0.264	1.653
Energy	181	1.044	0.149	1.653	183	-0.191	0.424	1.653	179	0.424	0.336	1.653
Economy	180	3.236	0.001	1.653	181	-0.492	0.312	1.653	184	-1.589	0.057	1.653
Industry	177	4.029	0.000	1.654	180	0.687	0.246	1.653	184	1.903	0.029	1.653
Inequalities	181	0.335	0.369	1.653	181	-0.789	0.216	1.653	179	0.672	0.251	1.653
Cities & Communities	177	0.188	0.425	1.654	184	0.467	0.320	1.653	181	-2.099	0.019	1.653
Production & Consumption	182	0.012	0.495	1.653	182	1.023	0.154	1.653	184	-0.606	0.273	1.653
Climate	175	-0.058	0.477	1.654	183	-0.073	0.471	1.653	175	1.600	0.056	1.654
Water Life	184	1.281	0.101	1.653	184	-0.568	0.285	1.653	184	-0.648	0.259	1.653
Land Life	183	4.020	<0.001	1.653	181	1.314	0.095	1.653	184	1.066	0.144	1.653
Peace	183	1.809	0.036	1.653	183	-1.781	0.038	1.653	181	1.345	0.090	1.653
Partnership	181	0.882	0.189	1.653	184	-0.264	0.396	1.653	184	2.972	0.002	1.653

DISCUSSION

Descriptive statistical results shown in Table 2 indicate that at pre-test stage three SDGs (8, 9, and 15) in the *knowledge* section have a median value of 2 which is not shown in any other SDGs of *attitude* and *action* sections. Interestingly, as shown in Table 3, the same SDGs improved significantly in the *knowledge* section (the highest improvement in all SDGs of all sections). At the post-test stage the median values for all three sections were more than 2. This indicates that knowledge related to these SDGs prior to the design-build project for majority of the students participated in this study was at a lower level compared to other SDGs.

The values reported in Table 2 indicate that the mean values (pre- and post-test stages) in the *knowledge* section is generally lower than those in the other two sections. This may indicate that due to lack of knowledge, a design-build project (or any other type of educational assignment) can be a great tool to improve the students' knowledge related to the SDGs. Generally speaking, the standard deviations of values reported for the *knowledge* section is higher than those reported for *attitude* and *action* sections; while students may have similar views in the *attitude* and *action* sections, the study shows that students have wildly varying degrees of knowledge of the SDGs. It makes sense since attitude and action are strongly connected to the culture of people.

After completing the design-build project, inferential statistical results tabulated in Table 3 indicate that the knowledge of students of all SDGs (except SDG 4 and SDG 13) have been improved, with six SDGs showing significant improvement (SDGs 1, 2, 8, 9, 15, and 16).

On the other hand, participating in the design-build project did not show any significant improvement in the attitude and action of students for majority of the SDGs (except in SDG 9 and SDG 17 in the *action* section). In fact, completing the project showed an adverse effect on most of the SDGs in these two sections. Since the action of students in SDGs 9 and 17 has been significantly improved, it shows that students not only understood that developing reliable, sustainable and resilience infrastructure and long-term partnership between organizations and governments are important, but also would be willing to act more seriously after finishing the project.

One of the main reasons that most of the SDGs (15 out of 17) have been improved or significantly improved in the *knowledge* section can be related to the fact that the project was done in an educational institution with more emphasis on the knowledge transfer. It also shows the importance of the CDIO approach and how effective it can be in a relatively short period of time.

Several CDIO standards were addressed in this study. The CDIO standard 3 was addressed through enhancing some of the personal, interpersonal knowledge and attitudes of students that were involved in the examined project. The CDIO standards 4 and 8 were also addressed through this research as the students were introduced to new concepts that are vital to sustainable and ethical engineering practice and were engaged to form their own opinions and respond accordingly.

The adverse effect of completing the design-build project on most SDGs (10 out of 17 in the *attitude* section and 9 out of 17 in the *action* section) can be explained in several ways. First of all, attitude is a settled way of thinking or feeling about something and changing it significantly in a relatively short period of time (six weeks for the design-build project in this study) will be quite challenging. Secondly, change (or significant change) in action requires a change in attitude, seeing as attitude and action are interconnected. Thirdly, after gaining more knowledge about the SDGs, students became more realistic in evaluating their attitude and action. This means that pre-test results in the *attitude* and *action* sections may not be as realistic as the post-test results.

It will be interesting to perform a similar study over a longer period of time (e.g. pre-test of freshmen students and post-test of the same students when they graduate) and/or in a different environment (e.g. employees of large size companies) to study the effect of the duration of exposure to the SDGs, as well as being exposed to real-life scenarios in a workplace.

CONCLUSION

The following conclusions can be drawn from this study:

1. The CDIO approach in educational institutions can improve (or significantly improve) the knowledge of students related to the SDGs. This is in line with the findings of other researchers as mentioned in the *introduction and background* section of this paper. Three CDIO standards were covered in this research.
2. Personal reflections on the SDGs by students were effective in improving their knowledge in a relatively short period of time.
3. Attitude and action (especially attitude) cannot be significantly improved in a short period of time as they are related to the culture of students.
4. Gaining more knowledge may help students to evaluate their attitude and action related to the SDGs in a more realistic way, and this may adversely affect the results for these two sections.
5. Long-term study on students group as well as performing similar study on group of practicing engineers will help to understand the matter.

LIMITATIONS

Due to the nature and duration of the study, there was no clear influence on the actions taken by students that would in return satisfy the SDGs. Future researches may be able to address the Longitudinal nature of this requirement through covering an extended period of time and looking further into how education about the SDGs truly influence the actions of students during their studies and beyond graduation.

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CDIO. CAN WE CONTINUE THE WAY WE ARE?

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ABSTRACT

In 10 workshops all over the globe, about 150 CDIO community members discussed the status quo, explored the fit between the current CDIO organisation and the changing environment, set goals, and substantiated arguments for a roadmap for CDIO 2030. They formulated new mission and vision statements for the CDIO Initiative and conceived ideas for the advancement of the CDIO framework. The goal setting and strategic thinking has culminated in a proposal for more structure to consolidate the community of practice with durable engagement and stronger involvement in orchestrated experimentation and sharing of practice. A broad consensus amongst the members exists about the urgency and importance to advance the CDIO framework beyond updating the syllabus or growing in numbers. Many members expect guidance for new developments in engineering education. The lack in evidence of the impact of the CDIO Initiative is an important issue. A major concern is the risk that the holistic nature of the CDIO framework is diluted. Whilst the landscape of engineering education has changed significantly over the past 20 years, in the outside world CDIO has almost become a synonym for conceive-design-build-operate projects. The initiative is at a crossroads of proceeding as before, or turning the tide and lead change in the next decades. The paper addresses the status quo as perceived by the members, the shift in engagement by newcomers and retirements from the community and the reformulation of the mission and vision statements for the CDIO Initiative. The paper gives an inventory of breakthroughs that are necessary to move CDIO back into a leadership position of innovative engineering education, if that is what we want.

KEYWORDS

Organisation, Community, Framework, Roadmap 2030, Mission, Vision, Standards: 12

INTRODUCTION

CDIO is a worldwide collaborative, formed in 2004. It is based on the commonly shared premise that engineering graduates should be able to conceive, design, implement and operate complex value-added engineering systems in a modern team-based engineering environment to create advanced systems, products and processes. The original community was formed by a core group of four institutions in two countries. They shared a common passion and need for the enhancement of higher engineering education. It has grown into a worldwide community with about 180 institutions (January 2021). Its individual members are mainly middle level engineering educators, education managers, autonomous engineering experts and people who have the ambition to become a leader or are already an emerging leader. Together they form the CDIO community of practice that has a culture built on professional networking, personal relationships, shared knowledge, and voluntary participation. The members have the common goal of enhancing, sharing good practices, developing ideas and understanding challenges in higher engineering education all over the globe. The CDIO Syllabus has been the leading guide for what engineering students should learn. Together with a set of 12 effective practices, the CDIO Standards, they form the basis for the CDIO Initiative. The community, organised in seven regions and supervised by the Council, is highly organic, informal and self-regulating by nature. It keeps things simple and informal, fosters trust and increases the shared body of knowledge. The members are empowered to design the types of interactions and determine the frequency that best meets their needs.

Communities of practice are like most living organisms (Wenger, 1998). They usually begin with an idea for a community and begin winding down when the community members feel the group has achieved its objectives or is no longer providing the value. With this in mind it is important to reflect on the progression of the CDIO Initiative over time, of which the conceptualisation began in 2001, is now in full operation and shows first signs of winding down in some regions and signs of growth and increased engagement in others.

A key parameter for the performance and engagement of self-regulating communities is goal setting (Locke & Latham, 2002). It looks questionable if the CDIO Syllabus and Standards and the lasting emphasis on student conceive-design-build-operate projects and a sharing of ripe and green examples of CDIO implementations or projects in progress, provide sufficient long-term value for community members who have joined five years or more. The goals these members had set for adapting the CDIO framework in their programme have been fulfilled, and little or no value remains. While the CDIO goals have remained the same since 2004, the landscape of higher education has changed significantly, and society, science and technology and teaching and learning are expected to accelerate change in the next decades (Kamp, 2016, 2020). If the CDIO Initiative does not only want to survive, also thrive in the long run, be on top of the world of higher engineering education, it cannot wait and adapt to change. It has to lead change and make change happen. It is therefore urgent and important to set new goals and perform a strategic analysis as input to the development of a CDIO Roadmap 2030.

GLOBAL DISCOVERY TOUR

In a series of 10 highly interactive workshops between 2017 and 2020 (Table 1) I have tried to reap the benefits of the *wisdom of crowds* (Surowiecki, 2004) and explored together with a broad representation of CDIO members what issues may impact engineering education and the CDIO Initiative until 2030. Following a theory of goal setting (Locke & Latham, 2002) we gradually developed long-term goals, ideas for change and contributions to a CDIO Roadmap. The outcomes of the meetings in Calgary, Sunshine Coast and Moscow (2017-2018) had the aim to develop an awareness about the strengths and weaknesses and undiscovered opportunities of CDIO. Their outcomes were elaborated in depth at the International Working Meeting in Delft (2019) and integrated in new formulations for a mission and vision statement, a provisional roadmap, and a list of strategic issues, of necessary breakthroughs. Details of the map and the formulation of the mission and vision statements were revisited at the EU/UK

Regional Meeting and the Asian Regional Meeting in spring 2019. The COVID-19 pandemic unintentionally made the CDIO International Working Meeting at Singapore 2019 the last meeting in the series. The discussions and analyses in Singapore focused on the necessary breakthroughs in membership, the organisational structure and the move to thought leadership.

Table 1. Series of CDIO Roadmap 2030 workshops

Location	Event	Subject	Time	# Part.
Offsite	Survey January 2017	Role of CDIO Initiative expected in the changing world of higher education	-	10
Calgary Canada	CDIO Annual Conference June 2017	Current state of affairs; discussions about who are we, how are we organised, what do we do and why?	2 hrs	40
Calgary Canada	CDIO Annual Conference June 2017	Who do we want to be in 2030: discovery of the impact on CDIO Initiative of extreme out-of-the-box utopian and dystopian future scenarios of higher education	2½ hrs	25
Sunshine Coast Australia	CDIO Fall Meeting November 2017		3 hrs	10
Moscow Russia	EU/UK Regional Meeting January 2018		2 hrs	12
Delft Netherlands	CDIO International Working Meeting October 2018	Goals setting, road ahead for the CDIO community and framework in 2030: what are we facing – what are we aiming for – what are we capable of? formulation of new Vision and Mission Statements; discovery of breakthroughs	12 hrs	32
La Rochelle France	EU/UK-Ire Regional Meeting January 2019	Sharpening of the Vision and Mission Statements; prioritisation and elaboration of breakthroughs	3 hrs	20
Dalian China	Asia Regional Meeting March 2019	CDIO as a follower or leader; stakeholder analysis: key expectations and needs	3 hrs	30
Aarhus Denmark	CDIO Annual Conference July 2019	Role and purpose of regions; differences in regional size and engagement	1 hr	10 (council)
Singapore	CDIO International Working Meeting November 2019	Strategic issues: community level, size, membership; connection to non-academic world; shift in focus away from project-based learning	7 hrs	50

All workshops were prepared, delivered and processed systematically by the author, except the one in Dalian that was prepared and delivered by the other CDIO Co-director. All workshops had the same template. They were introduced by a brief introduction about the status and activity flow of the day, after which the participants chose the splinter session of their specific interest, discussed in these sessions with four to eight members each, and reported back on flipcharts or whiteboards in a plenary session. The flipcharts and photos of the whiteboards were taken home and contained in a 55-page logbook. Apart from pictures of the sessions, no personal presence logging was made. The International Working Meetings in Delft and Singapore were supported by the Dutch Flatland visualisation agency. Their staff prepared templates for the assignments in the splinter and plenary sessions and helped to envision the outcomes and activate the change. The visuals they produced structured and recorded the thinking in sessions and became the centrepieces at the plenary wrap-up discussions. They are available for future work.

The first workshop in Calgary reflected on the fit between the current state of affairs and the environment: who are we, how are we organised, what do we do, and why? In six separate groups the participants analysed Community, Inspiration, Dissemination, Education innovation, Staff professionalization, and Industrial relationship.

To provoke deep thought about the future evolution of the CDIO Initiative, an investigation of neither projective scenarios (linear extrapolations of today's trends) nor prospective scenarios (back casting from a future vision) suffices. Instead, the participants of the second workshop in Calgary and the workshops at the Sunshine Coast and Moscow investigated the impact on the CDIO Initiative from 10 different combinations of extreme out-of-the-box utopian and dystopian future scenarios of higher education. An example of such an extreme scenario is the combination where commercial brokers take over the educational role from higher education institutions ("professorless universities") and at the same time learning machines (AI) take over most non-routine cognitive engineering activities. Another example is a scenario where all curricula are unbundled into certified knowledge packages for personalised learning and at the same time universities have segregated into research and education universities.

At the International Working Meeting at TU Delft we made a discovery of strategic issues deemed necessary in the CDIO Initiative and the community structure (Bryson, 2018). We discovered strategic issues like turning points and emerging needs for the organisation, by imagining future scenarios and painting desired pictures of the future that would meet the intended needs. Thus we developed new perspectives for the CDIO community and framework. In subgroups of six to eight persons we put ourselves in the role of a CEO, an engineering student or a dean of an engineering department and imagined what these personas would expect from the CDIO community of practice and the CDIO-educated graduates in 2030. To establish a basis for a common ambition we established cover stories about major achievements of CDIO in 2030 in a prominent magazine, newspaper or other media that has great topical value and attracts considerable public interest. The combined output of the personas and cover stories enabled the participants to formulate drafts of a new vision and mission statement. The working meeting was concluded by the discovery of breakthroughs that are essential to meet the expectations from the personas, turn the virtual cover stories into reality, and take proactive measures.

The participants of the Regional Meetings of Europe/UK-Ireland in La Rochelle and Asia in Dalian sharpened the mission and vision statements and complemented, clustered and prioritised the strategic issues. Together they set the stage for the next working meeting in Singapore.

At the International Working Meeting in Singapore the new mission and vision statements were presented and used as a baseline for the development of a strategy for CDIO to become a thought leader in engineering education (again). In five splinter sessions alternative implementations were generated for the breakthroughs 'Size and organisation of the community of practice', 'Leadership to influence', 'Shift in focus', 'Sustainable institutional implementation', and 'CDIO for non-engineering. The working meeting was concluded by a brainstorm about the process to develop a CDIO community of practice with durable engagement, better accountability and more shared practice, and a process of cyclic evaluation of the CDIO framework as a whole and the individual community members on a regular basis.

AWARENESS ABOUT THE STATUS QUO

The participants of the first workshop in Calgary established a common point of departure by reflecting on the current state who we are, how we are organised, what we do and why. The following paragraphs describe the main findings.

The CDIO community is open to the full spectrum of schools and universities in higher engineering education all over the world. It is free from cultural, religious or political issues. Tensions exist between the openness, the feeless membership with its potential risks of unlimited growth and uncontrolled quality, and the risk of a gradually waning commitment by the members. Today's CDIO is known as an evolving community of practice. The community has 182 (January 2021) member schools that are spread non-uniformly over the seven geographical regions: Europe (71 members), UK-Ireland (16), Asia (47), North America (19), Latin America (19), Australia-New Zealand (8), and Africa (2). As the community expands and evolves differently across the regions, it is critical to understand how to remain relevant, especially for members who have adopted the CDIO framework already for many years, and how to deal with changing expectations and different levels of engagement and commitment over time, which may be different per region. Agility to different needs and change is key.

CDIO portrays itself as a framework of tradition, design-build-implement projects and not so much about education innovation. The interest in design-build-implement projects is on the decline. A bibliometric study (Meikleham, 2018) indicates a halving of CDIO conference papers that address design-implement-operate projects since 2012. It mentions that an overemphasis on project-based learning could easily lead CDIO to become synonymous with a community of practice for project-based learning, thus facing the risk of diluting the unique value proposition of the CDIO holistic framework for educational reform. It is therefore necessary to provide evidence about the unique competency levels of graduates of CDIO programmes and inspire administrators and policy makers by referring to the methodology as modern engineering education, in which experiential learning is important. The framework has the potential, but currently misses the strength, to connect engineering education to the world of work and accreditation agencies. There is a very strong consensus across the regions that the CDIO Initiative requires very strong relationships with industry. It is the engineering business companies who know the needs and the competency attainment levels of young graduates of our schools. Although closing the full cycle, from education and student to alumnus in industry to industrial leader, is a long game, we urgently need to evaluate CDIO graduates' performance and career routes in comparison with non-CDIO performances. For engineering business the lack of evidence is probably an important reason for their limited awareness of CDIO as a "brand" of engineers.

The dissemination of good practices in papers, presentations and workshops is important but does not lead to the momentum for systemic change. Today's CDIO Initiative lacks a leading profile in innovative engineering education. Nowadays the educational innovations in member institutions are often local fragmented initiatives whose results are shared at the conferences or regional meetings. There is a strong desire to transform CDIO into a community of practice where educational developments are harmonised into collaborative efforts. The continuous professionalisation of staff is important and the community is a rich source of experts. If we aim CDIO to develop into a leader in innovative engineering education, training in innovative methods of teaching and learning such as interdisciplinary education, online teaching, blended education, digital assessment of engineering questions, micro-credentials-for-credit, corporate learning in a digital environment, offer excellent opportunities. But they will only succeed if resources or incentives for such trainings and reskilling can be provided through CDIO membership.

WHAT IFS

Strategic thinking in the workshops of Calgary, Sunshine Coast and Moscow about combinations of hypothetical extreme scenarios of future engineering education of course could not yield a list of realistic opportunities or achievable ambitions for the CDIO Initiative. However, the process in these workshops opened the minds of the participants and resulted in many hints and guidance for the formulation of the mission and vision statements and the identification of strategic issues, the breakthroughs. Many of the participants realised we probably overestimate the change that occurs in the next couple of years, but underestimate the change that will occur in the next decades (Bill Gates quote). In the following section I have selected a representative set of concerns, opportunities and challenges that were identified when thinking and analysing the extreme scenarios of higher education. I have projected them on the themes and scenarios that were identified as projective scenarios as described in the MIT study about the global state of the art in engineering education (Graham, 2018). For sure these are realistic.

Shifting leadership in engineering education

The first scenario is about the shift of the leadership in innovative engineering education to “powerhouses” in Asia and Latin America. Because the CDIO framework has its roots in Western society, it does not fully reflect the realities of the Asian or Latin American world and risks to gradually loose its relevance on the global scale. In the workshops people came with evidence that regions, or countries within a region, are developing an own identity of the community of practice that better matches the regional needs. If the global CDIO is resilient enough it has the opportunity to combine these forces and thus lead the enhancement and innovation in engineering education in these regions. The shift to the East and Latin America has an immense growth potential for engineering education (millions of engineering students more) and the CDIO Initiative as well. Vice versa the CDIO members in other regions can harvest from the new insights and rapid developments in education in China, India and Latin America, and reap the benefits of cultural learning in these regions. Quite some participants of the workshops expect the CDIO framework has to incorporate the different contexts of the regional traditions, culture and ethics in the Syllabus and Standards. Relationship building and maintenance with Chinese and other Asian partners and collaborators in Latin America is therefore of the utmost importance. It is clear that the CDIO framework and community of practice has to be open and easily adaptable to such rapid changes in the landscape of higher education.

More relevant and outward facing curricula

In the second scenario described by Graham, engineering curricula become more socially relevant and outward facing, and the desire to broaden student experience grows. This scenario about the rise of a more *humanitarian engineer* may open the CDIO Initiative to many new minds. The limitation to engineering disciplines has to be opened to multi- and interdisciplinary studies that link much better to designing solutions for complex societal problems than the traditional disciplinary way of thinking. We may have to tailor the framework to include more perspectives of humanities and social sciences, and call for more industrial engagement to better understand the needs and expected attainment levels of technological literacy. An interesting opportunity for CDIO was identified in striking up conversations with corporate universities that could lead to interesting cooperation between multinational industrial companies and the CDIO community of practice. Liberal arts sciences will develop into a strong influencer on our CDIO thinking. It will put more emphasis on impactful engineering with sustainability, ethics and responsible innovation. This shift is expected to happen simultaneously with the rise of machine learning in the engineering profession. Increasingly intelligent machines will support or replace the engineer in doing non-routine cognitive design, engineering and research work. This will increase the interest in graduates who not only have good working knowledge in the fundamentals in science and technology, but distinguish themselves by excellent creativity, empathy and ability to transfer knowledge to other contexts. These are facets that are still undiscovered territory in CDIO.

On-demand learning

The third scenario is about the trend of on-demand learning and the increasing desire for free choice and flexibility by the students. Today's Generation-Z engineering students are more oriented to their ambition, aspiration and future career (Twenge, 2018; Kamp, 2020). For CDIO an interesting opportunity develops in taking a consulting role for enterprises and member universities in the establishment of engineering profiles with coherent course packages or selection menus that meet personal needs. In the extreme case, CDIO could take a leading role as a broker of (accredited) course packages for credit for its community members. CDIO could also develop into a consultant for commercial brokers or platforms for online education and provide reference frameworks for engineering course content that is accredited by international accreditation agencies. The CDIO community of practice is full of experts and, in collaboration with industrial experts, in an excellent position to train faculty to operate in diffuse curricula and coach them in the role of chef de menu. The growing numbers of students who need guidance and monitoring of their individual study programme may offer another opportunity for the CDIO community. On a collaborative basis it could support students in career and study planning. It is obvious the organisation and framework have to be resilient enough to accommodate such major changes. In this respect the COVID-19 virus pandemic is a wake-up call for the future of higher education and the CDIO Initiative. The framework has to be made resilient and can no longer be a one-size-fits-all.

Need for CDIO to be agile

The variety in thoughts and ideas about opportunities, risks and threats for the CDIO Initiative will not all reach operational level in 2030. But we have to anticipate to their arrival in the coming decade. They show the urgency for the development of a strategy how CDIO should deal with changes in higher education. These will be characterized by more on-demand and personalised learning, partly online courses for credit, AI-assisted tutoring and peer learning, on-campus hands-on education, interdisciplinary education with more emphasis on societal relevance and impact than we are used to. CDIO has to make a choice to either taking a leading role in shaping this change, or just adapting to the changes. No doubt that any of these choices needs a more resilient CDIO community and framework than we are used to.

AMBITIONS

The International Working Meeting in Delft and the Asian Regional Meeting in Dalian were dedicated to goal setting and the discovery of the ambitions and expectations of the members of the CDIO community of practice. The participants teamed up in the role of a CEO of an engineering business, an engineering student, or a dean of an engineering department and then discussed for a 10-year time horizon *What do I expect from the CDIO collaborative network*? and *What do I expect from CDIO-educated engineering graduates*?

Pride and ambition

The discussions expressed pride, ambition and a desire for a prominent position in higher engineering education.

a. CDIO Initiative: a reliable and qualified community of practice for continuous faculty professionalisation and peer-to-peer sharing of didactic methods in CDIO learning, a "broker" of lifelong learning modules for engineering professionals, consultation in the reform of curricula, a framework that can be used in the development of a national qualification framework, an inclusive network that is open to academia and business companies, engineering as well as non-engineering, with a significant positive impact on academic engineering degree programmes.
b. CDIO-educated graduates: prepared to make a difference, mastering a good ensemble of engineering expert knowledge and professional skills, a mindset of sustainability, responsible engineering and innovation, ready for the Industry 4.0 world of work with top-notch skills in computational thinking, data literacy, systems thinking, integration of physical and cyber systems, and keen on authentic and impactful design and research problems from industries and institutes.

In another activity we established cover stories about a major achievement of CDIO in 2030 for a prominent magazine, newspaper or other media with great topical value. They provided more basis for a common ambition: *Who do we want to be in 2030?*

Influencer and springboard

At a higher abstraction level, it is our aim that graduates of CDIO degree programmes profile as future leaders of engineering businesses. We want to be an influencer and that means we have to develop into a frontrunner in engineering education, take leadership and make change happen on a global scale. We want to be a springboard for innovative higher education and faculty development, even beyond the domain of engineering. To achieve these goals, CDIO shall satisfy the following enablers:

i. an open mind and agile attitude to change (differentiation in roles of teaching staff, changing technologies, digital transformation)
ii. a resilient organisation to adapt to (rapid) change (a community with different levels of engagement, regions that give the framework a local identity, special interest groups, different set-up of events like chase-the-sun workshops)
iii. limited growth while being an open community
iv. membership and engagement (industries, (also corporate) universities, NGOs, students, leaders, middle level engineering educators, education managers)
v. online visibility (exposure, PR, website, apps, online instruction materials)
vi. benchmark of effective practices and a credit transfer matrix between CDIO partner institutes
vii. collaboration and joint initiatives

MISSION AND VISION STATEMENT

On the basis of the ambitions in the previous paragraph, the participants of the workshops in Delft, La Rochelle and Singapore were challenged to update, rephrase and sharpen the existing vision statement (www.cdio.org):

"The CDIO™ INITIATIVE is an innovative educational framework for producing the next generation of engineers"

Rephrasing the vision statement and establishing a new mission statement for CDIO are important milestones towards the CDIO Roadmap 2030. Rethinking the vision statement should answer the question 'where do we aim to be?' The statement communicates the purpose of the CDIO Initiative and explains why we are an active member of the network. It is a source of inspiration, guidance and motivation for future work.

Figure 1. International Working Meeting Delft: drafting a new CDIO vision statement

The CDIO Initiative lacks a mission statement. Such statement talks about how we will get to where we want to be. It answers the question 'what do we do, what makes us different?' It focuses on the present, leads to the future and describes the purpose in relation to our stakeholders' needs. Its prime audience is the CDIO community itself.

The outcomes of the discussions at the working meetings were that the vision and mission statements should amplify aspects of global coverage, ambition, leading collaborative network, developing innovative engineering education, openness, agility, the dynamic nature of the framework, aiming to improve continuously.

After lengthy and intensive deliberations and iterations in three consecutive workshops, the formulations of the vision and mission statement for the CDIO Initiative were agreed upon as follows:

VISION STATEMENT

"To be the leading worldwide collaborative network for innovative engineering education to produce responsible engineers who make a difference in the world through innovation and creative workable solutions"

MISSION STATEMENT

"Building community capacity to make an open flexible and evolving framework for the advancement of engineering education by an inclusive collaboration and a sharing of effective practices for local impact"

INVENTORY OF STRATEGIC ISSUES

CDIO organisational structure

With the newly formulated ambitions in the vision and mission statements, and a list of impactful changes CDIO will experience in the next decade, nobody had any doubt that we cannot continue as we have done over the past 15 years. At the workshop in Delft, La Rochelle and Dalian the participants got the assignment to discover breakthroughs, turning points, that are essential to future-proof the CDIO Initiative and align the activities with the mission and vision statements and thus meet the expectations, turn the ambitions into reality and give guidance and control. Figure 2 shows an overview of the breakthroughs that were identified at the three workshops. Each breakthrough was tagged to one of 11 themes. The four themes Membership & Organisation, Regions, Thought Leadership, Marketing & Promotion were clustered into the comprehensive theme CDIO Organisation. It is expected that many breakthroughs within the CDIO Organisation will enable breakthroughs in the other themes.

CDIO products and services

Besides the CDIO Organisation, five other breakthroughs in CDIO products and services received high scores for importance and urgency:

1. the role the experts in the CDIO community should play in the lifelong learning of staff of member institutes;
2. bringing experts together for joint development of a springboard for innovations, with particular interest in the development of agile curricula;
3. sharing expertise, for instance by the establishment of temporary special interest groups, particularly with respect to online and blended learning, unbundling of curricula and dealing with micro-credentials or digital badges, and the integration of digital literacy in engineering education;
4. thought leadership about achieving durable implementation of CDIO in member institutions; developing a recognition of the CDIO graduate competencies may give it a boost at national and international level;

5. developing strong relations with leading industrial companies. Making connections with governmental agencies to use the CDIO framework for national qualification frameworks for higher engineering education (of special interest for the Asian region).

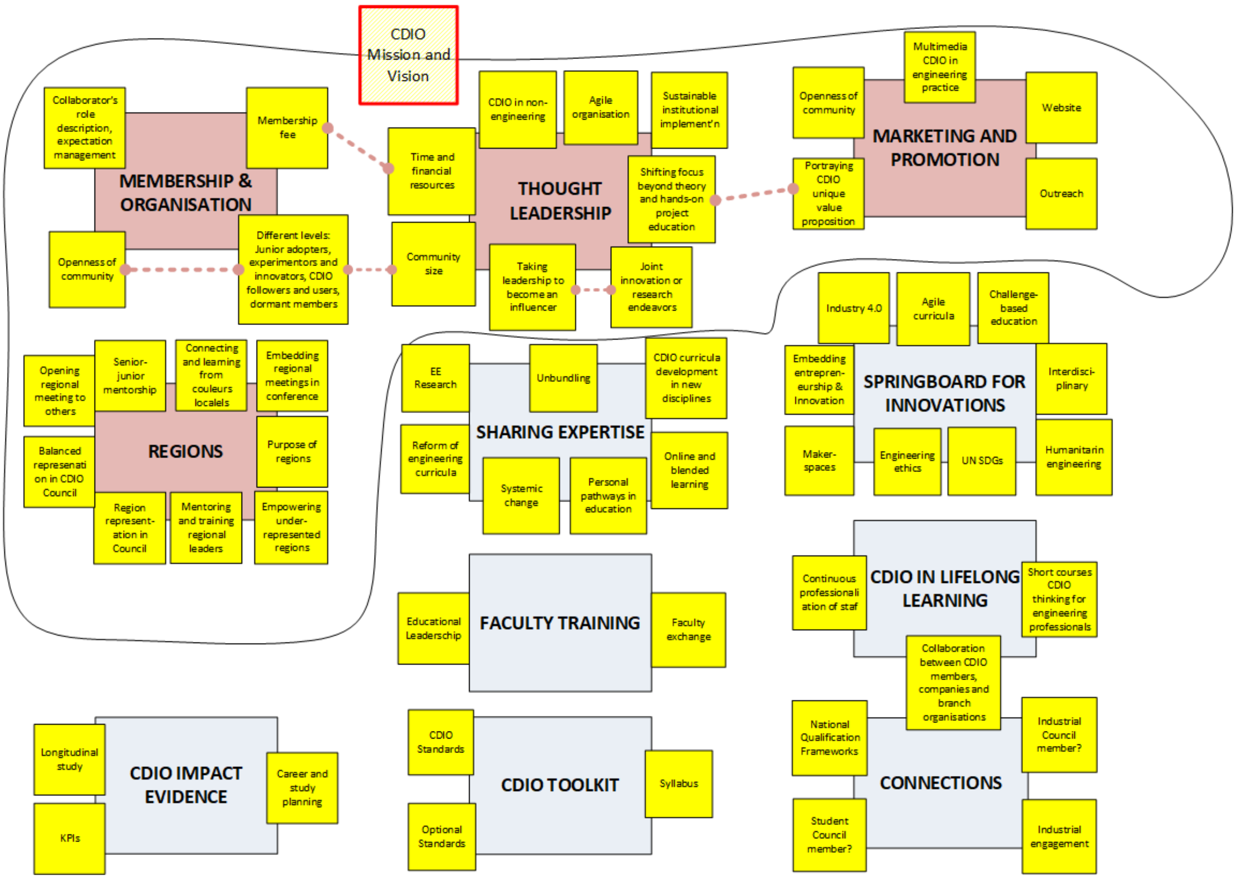

Figure 2. Inventory of breakthroughs and all kinds of facets.
The enveloping curve marks the breakthroughs in the CDIO organisation.

FROM VISION TO THOUGHT LEADERSHIP

The major activity at the Singapore International Working Meeting was the development of a strategy for CDIO to become a thought leader in engineering education. In five splinter sessions the 50 participants conceived their ideas about community size, leadership to influence, shift in focus, sustainable institutional implementation, and CDIO for non-engineering. These breakthroughs were all connected to the theme of Thought Leadership (Figure 2).

Limiting the size of the CDIO community

The discussion about the community size emphasized that it is the commitment of the members of a community of practice that matters, and that commitment is often driven by the size of the community (Figure 3 left). Although the regional structure helps in this respect, the commitment in some regions has already dropped so low that even the few remaining members might consider to retire the community. The workshop participants proposed to investigate the pros and cons of different levels of membership, and relate this to better recognition and resources for innovation.

Influence and recognition

Although previous discussions resulted in a desire of CDIO to become an influencer in innovative engineering education, the workshop in Singapore refined this point of view. The added value of being a member of the CDIO community is to inform, inspire and influence the members *within the community* by evidence-based innovations, experimentation and research in education. Recognition (personal as well as institutional) is important in keeping the professional commitment alive in engaging and adding value.

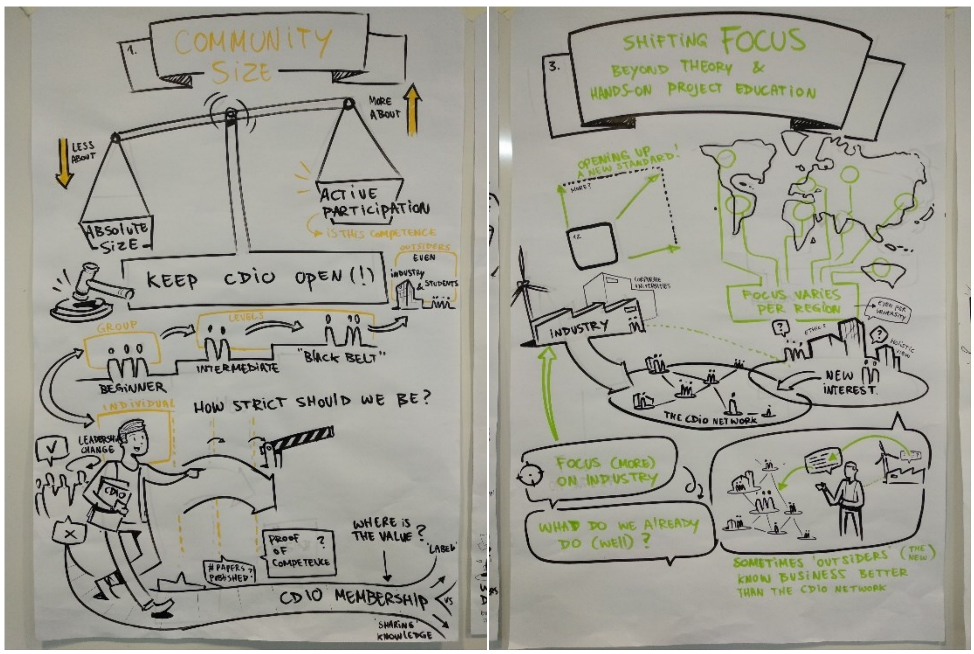

Figure 3. Visualisations of the discussions about community size and shifting focus away from project-based education

In a rut of project-based education

In the discussion about CDIO being increasingly perceived by outsiders as a synonym for project-based education, the participants expressed their concerns that this perception limits and dilutes the holistic nature of the framework (Figure 3 right). It may explain the winding down of senior members in regions where other communities or associations apparently add more value to innovative educational methods that are on the horizon, such as challenge-based learning, blended learning, collaborative learning in the digital age, responsible engineering, than a CDIO membership. Although the needs and fields of interest in CDIO very much depend on the region or institution, keen interest exists in sharing curricular developments and pedagogical practices for engineering ethics, sustainable engineering, holistic engineering, integrating physical and cyber systems in engineering, etcetera. It is therefore crucial to get industries and corporate universities involved in the community. To turn the tide, it is also recommended to select thought-provoking conference themes, portray them and make them leading in the paper and keynote selection, and reduce the things we have always done.

Durable membership

In the discussions about the durability of institutional CDIO membership (Figure 4 right), the following concerns about recognition of the membership were a prominent issue: the decrease in added value for institutions that have adopted CDIO for a longer period of time already, the lack of support from higher management or government. There is a clear need to acknowledge and give more exposure to the active member institutions and individual contributions. To strengthen the exposure, it is desirable to facilitate individual memberships and memberships by industries, industrial branch organisations, accreditation agencies, international student bodies such as BEST (Board of European Students of Technology) and thus emphasise relevance and importance.

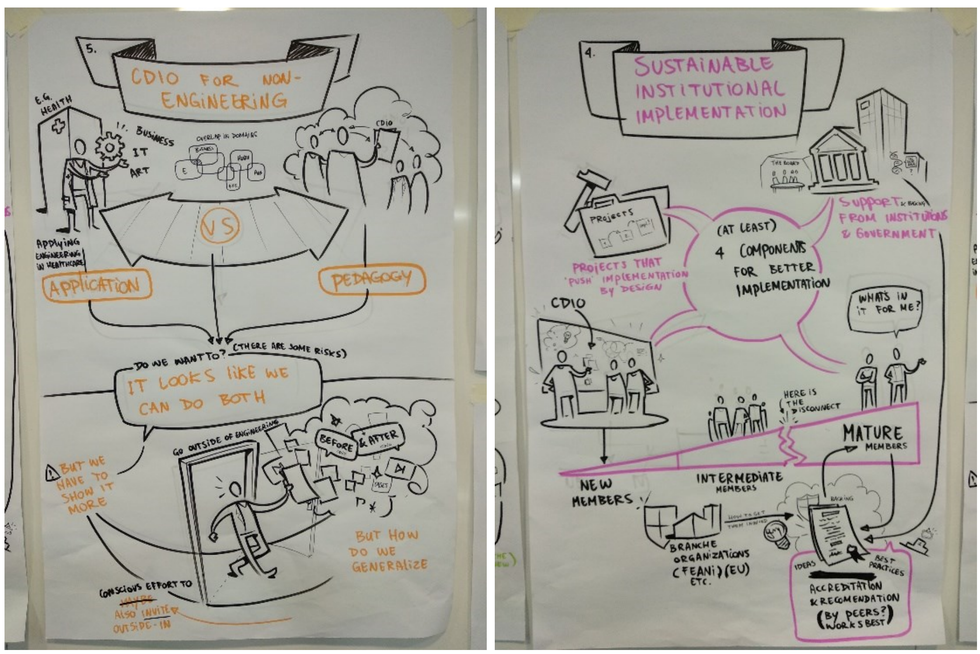

Figure 4. Visualisation of the discussions about
CDIO for non-engineering and Sustainable implementation

CDIO in non-engineering disciplines

Last but not least we discussed the desire to extend CDIO to non-engineering disciplines (Figure 4 left). Evidence of the added value of the CDIO educational framework will be necessary to convince others. The pedagogy of engineering disciplines is easily transferrable to other disciplines and there is no doubt the CDIO framework is relevant for non-engineering disciplines as well. We should actively welcome non-engineering practitioners to our events and activities, inspire, not necessarily lead them, to change from engineering education point of view. It is not our aim to generalise the CDIO framework.

Summary

The plenary session after the five splinter sessions concluded that:

A. the effectiveness of the CDIO framework and the value of being a member of the community shall be demonstrated by evidence and portrayed to the outer world, so that member institutions can take advantage in accreditation or promotion of career profiles of their graduates.

B. The community is growing rapidly whilst the engagement in the community diminishes over time, as it no longer provides the value that is desired, or member institutions experience insufficient recognition for their contribution and engagement. Different levels of membership for a durable engagement, more recognition and accountability, and an endorsement by institutional management, should give new momentum to activities and possibly open up possibilities for funding of activities. An increase in diversity in membership may give a boost to engagement;

C. There is an urgent need to strengthen the connections to the industrial and non-academic world and actively embrace non-engineering disciplines;

D. The long-lasting emphasis on project-based education as one of the assets of the CDIO methodology has become a threat for the holistic CDIO framework. Many members look forward to the next step and are eager to learn from each other about teaching ethics, sustainable design, holistic engineering, digital learning, collaborative learning in a digital environment, and the use of mindsets in engineering curricula.

RETHINKING CDIO AS A COMMUNITY OF PRACTICE AND CHANGE AGENT

The CDIO community of practice is a group of practitioners who have a common interest in engineering education. CDIO is supposed to be a place of exploration, experimentation, evaluation and reflection. In a workshop at the Singapore International Working Meeting we addressed the desire and need to rethink the rapidly growing community of practice and assure durable quality and value of the CDIO Initiative.

Organisational structure

To date the CDIO community of practice has a flat structure. Apart from the Council there is no hierarchy or differentiation in membership. Each member is part of a regional community that is coordinated by a Regional Leader who is a member of the Council. The CDIO Initiative is presided over by a 15-member Council core team that forms the heart and organises, nurtures and operates the community.

A group of 15 to 20 *active* members works closely with the Council to help shape the definition and direction of the CDIO community of practice. These members are actively engaged in defining and developing the community's shared vision, its purpose, the roles, strategies for interaction, review the applications of candidate members. They regularly attend the Online Leaders Meetings and play a vital role in the CDIO International Working Meeting and regional meetings.

The third and biggest group of the CDIO community is formed by the approximately 140 institutions that participate *occasionally* in the CDIO events. They feel a connection to the CDIO Initiative and engage on a limited basis. They mainly focus on acquiring knowledge and experience for the benefit of local development in their institution. They are members who have a more casual interest in community activities, can be newbies as well as members who consider retiring the community.

Finally, there is a small group of *peripheral members*. They are the least connected to the community and only connect for instance to consult the Syllabus or Standards or provide specific consultation or service to the community. It might be interesting in future to also assign probationary members to this group: members whose application has open points, the experience and familiarity with CDIO is still low, or membership awaits for evidence of managerial support and the viability and feasibility of the sometimes overambitious plans for the transformation of curricula to meet CDIO Standards.

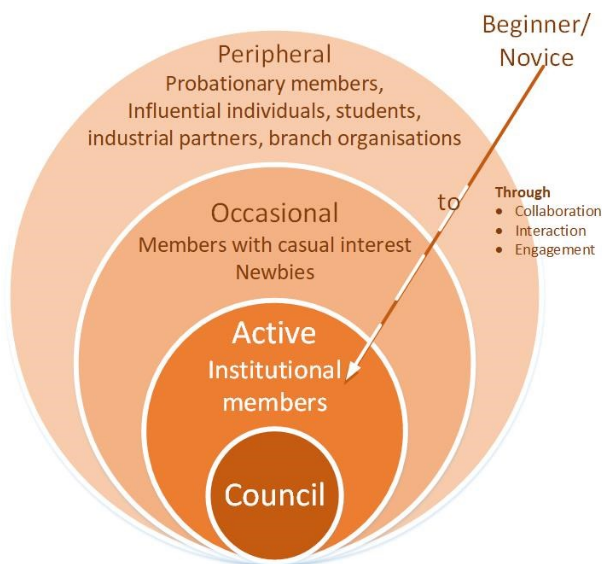

Figure 5. Community organisation with different levels of membership

In the workshop we conceived the explicit community structure shown in Figure 5. It has the goal to create more durable engagement and accountability, provide more clarity about expectations and roles, and more recognition of active members. Making this structure explicit might enable the possibility to charge a membership fee. The fees could be used for the funding of collaborative advancements by active members and stimulate active involvement by more members. It may also be used to hire a (part-time) CDIO professional for preparing or assessing peer reviews, promoting CDIO to industry or implementing any other recommendations mentioned in the Conclusions.

Using evidence to advance the CDIO Initiative

The lack of evidence of the impact of CDIO membership triggered the discussion how we might gather relevant data that would enable us to evaluate the positive impact of the CDIO framework. On the one hand we discussed the need to consult human resources professionals of engineering businesses on a regular basis. On the other hand, to stimulate growth and development, build up a history of evidence, activate the members in their role of sharing best practices, and spot candidates retiring or already dormant members, it was proposed to introduce a 6-year evaluation cycle for each member institution. The cycle should lead to a minimum of extra overhead and when appropriate, run simultaneously with a national visitation/accreditation cycle. An appropriate first peer-to-peer review for an institution would comprise of the evaluation of the impact of a curricular adaptation to the CDIO framework, a comparison with the plan presented in the membership application, and a fruitful discussion about the intentions and planning in the next period.

The making of *an evolving framework for the advancement of engineering education by an inclusive collaboration and a sharing of effective practices* (as formulated in the new mission statement) needs a trustable, transparent and uniform procedure. This procedure has to reflect that the cyclic review shall be of direct benefit for the institution and have a spin-off to the global CDIO Initiative. For the latter it is important to understand what evidence at CDIO level we are looking for and how this evidence can be collected and interpreted. The information gathered from the cyclic evaluations and reflections will be analysed at a higher aggregate level (region, global community) following a transparent process. Its goal is to identify local, regional or global needs and trends and thus give guidance to the advancement of the CDIO Initiative.

CONCLUSIONS

The CDIO community of practice is a key element of the CDIO Initiative. It is self-organising, self-regulating and its members have the freedom to determine their own level of engagement. Like most living organisms, communities of practice have a natural life cycle, and CDIO is no exception.

The need to move forward

CDIO is a holistic innovative framework for engineering education. Gradually it has become synonymous for project-based education in teamwork. For many institutional members who have adopted the framework, the value of the membership diminishes over time. Engagement shifts to regions (Asia, Latin America, Eastern Europe) where high interest exists in the enhancement of engineering curricula by adopting the CDIO framework. To avoid a winding down of interest and a retirement of member institutes, the CDIO Initiative has to advance more thoroughly than updating the Syllabus and sharing fragmented local developments alone.

In a global discovery tour of 10 workshops over the globe, new goals have been set and new mission and vision statements have been formulated. They reflect the choice and ambition of the community to *make an open flexible and evolving framework for the advancement of engineering education.* The community shall collaborate in the development and guidance of curricular enhancements and the advancement of pedagogies in engineering education that are necessary in the light of the rapid developments in technology and society. This requires strategic thinking by the Council, clarity in responsibilities and expectations in a transparent community structure, a dedicated group of active members with commitment, and funding by its members and potentially external parties.

***Recommendation 1*: The Council to adopt the new CDIO vision and mission statement and develop, implement the new strategy with transparency and decisiveness in community structure, events and activities, and convey the change in message in (introductory) workshops and website, or make the conscious decision to proceed as usual.**

***Recommendation 2**: Dare to choose and give guidance on curricular developments and pedagogical practices in engineering education that specifically reflect the changing mindset, working methods and competencies in the era of digitalisation in the world of education and technology.*

The need for evidence of positive impact

The value of membership to the community of practice lies in its members. Today's flat structure and open community leads to unlimited growth in community size and untraceable involvement and engagement. To stimulate growth and development, build up a history of evidence and activate the members in their role of sharing best practices, a broad desire exists to introduce a peer-to-peer evaluation cycle for each member institution at regular intervals. A research framework and a plan for data collection and analysis have to be set up. At the highest aggregate level of the CDIO Initiative, the gathered information will be used to build up a history of evidence about the positive impact of CDIO on the quality of engineering education and its graduates. It will enable the identification of regional or global trends that give guidance to the advancement of the CDIO Initiative.

***Recommendation 3**: Develop and implement a cyclic peer-to-peer evaluation process by and for the members to build up a history of evidence on local and global level, and stimulate the members to share practices and improve continuously.*

The need for recognition

The need for evidence, addressed above, directly relates to the high needs for recognition. Leading persons need recognition by the higher management in their institution. Active institutions want to be recognized for their contribution to the CDIO Initiative and look for ways how the benefit of a CDIO membership can be used in their national accreditation framework. There is a strong desire that the engineering competencies of the graduates of the CDIO programmes are recognized by the world of work. This can only be realised by a network of trust and quality that has strong connections with leaders and human resources professionals in leading industries, corporate universities, NGOs and accreditation agencies. A transparent community structure, a quality process for the admission and up-to-date evidence of an inclusive collaboration and sharing of effective practices are conditional for a durable recognition by performance.

***Recommendation 4**: Strengthen the ties with higher management and human resources professionals in leading industrial companies, corporate universities and accreditation agencies and given them the status of peripheral membership. Actively reach out to non-engineering programmes.*

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BIOGRAPHICAL INFORMATION

Aldert Kamp has been the Co-director of the CDIO Initiative since 2017. He is the immediate past Director of Education at TU Delft, the Netherlands. He has been deeply involved in the rethinking of higher engineering education with a horizon of 2030 and beyond. More than 20 years of industrial experience in space systems engineering, more than 18 years of academic teaching, educational management and leadership, and an in-depth study of trends in society, science, technology and engineering, and higher engineering education, have made him a thought-leader in future engineering education. He is the author of the thought-provoking reports *Engineering Education in a Rapidly Changing World - Rethinking the Vision for Higher Engineering Education* (2016) and *Navigating the Landscape of Higher Engineering Education - Coping with decades of accelerating change ahead* (2020). From 2014 till 2020 he was a Co-leader of the Dutch 4TU Centre of Engineering Education (4TU.CEE) that experiments and innovates in higher engineering education. Since July 2020 he is self-employed in his one-person Aldert Kamp Advies business.

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CHOOSING THE RIGHT D FOR DESIGN

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ABSTRACT

In the current CDIO V2.1 standard (2016), there is no formal definition of what design is or what process should be employed. Instead, it is left to the educator to figure out what is the right way to proceed. Among philosophers of design, there is no agreement on the nature of design processes. Design is often taught as an iterative method taking a developed list of requirements and trying different combinations of elements until a satisfactory solution is found. Knowing which elements are worth investigating is often said to be only gained through reading background material and experience. There are alternatives in the form of formalized design methods, including Axiomatic Design and Google's Design Sprint. This paper presents an overview of these methods to provide opportunities in hybrid design frameworks for the CDIO educator. When properly informed, both students and teachers can choose or create the right D in CDIO to fit the project or discipline.

KEYWORDS

Design, Axiomatic Design, Sprint, Requirements, Standards: 5, 7, 8

INTRODUCTION

The second element in the CDIO name is "design", so one might assume a great deal of literature published on the subject and how it should be implemented. In the most recent CDIO proceedings, there are a few articles that give specific guidelines to using a particular method to design, such as Paul and Behjat (2016) explaining how to use SCRUM for an integrated design project. Tanarro *et al*. (2015) address the problem of teaching engineering design to a multidisciplinary audience. They leave the method of design open. What seems to be lacking is the meta-design phase of deciding what kind of design method to use. To make an informed decision, we must first consider what the CDIO standard states regarding design and suitable options to choose from. Perhaps the best question to start with is: "What does it mean to design?"

Background

While Crawley, Malmqvist, Östlund, Brodeur, and Edström (2014) mention design a lot, a clear definition of *design* is missing. The CDIO standards characterize design as (Standard 1, p. 293): "The Design stage focuses on creating the design, that is, the plans, drawings, and algorithms that describe what will be implemented."

Standard 4 (p. 296) suggests that: "[s]tudents engage in the practice of engineering through problem-solving and simple design exercises, individually and in teams." Indeed, how to *design* is disputed.

Newell and Simon (1972) describes the design process as a sequence of discrete steps that are driven by a plan. The goal of designing is to optimize a candidate design for known constraints and objectives. Most design methods proposed in Section "Traditional Design Methodologies" describe such sequences of steps.

Schon (1983), on the other hand, observes that designers do not follow such a model in practice. Indeed, such a model of discrete steps has been criticized in software engineering by Royce (1970) as infeasible for sufficiently complex projects. Indeed, the goals are often unknown when the design process begins and, and the constraints and objectives change (Brooks, 2010).

Today, software projects follow an *agile method* (Beck et al., 2001), which focus on customer interactions and short iterations to solve specific design problems. Design is instead viewed as a creative endeavor guided by intuition and emotion.

CDIO Standard

The CDIO standards recommend teaching about design (Standard 1) and provide design exercises (Standard 4). We report on different approaches to design, and how design exercises are used at Reykjavik University. Also, design-implement experiences should be included in the curriculum (Standard 5). Among others, the course on Internet of Things is such a design-implement exercise. This course is taught as a multi-disciplinary course (Standard 7) with mechanical engineering students, mechatronic students, computer science students, and software engineering students. This course exhibits that different approaches to design have to be addressed, and interpersonal skills have to be trained.

The course is also an active learning experience. After an initial guidance, the students are designing and implementing their solution, getting only the teacher's guidance, and their support when requested.

TRADITIONAL DESIGN METHODOLOGIES

This section describes general design methods that are universally applicable in the sorts of projects commonly desired in courses. At an abstract level, the purpose of design is to move from an immaterial concept to something more concrete. C-K theory (Hatchuel & Weil, 2003) describes this as the process of mapping concepts to knowledge and examining the connections between these various nodes[1]. For use in a focused class trying to go from a concept to a prototype that can be operated, this method is too general for students to see how it applies to their specific design.

Instead, we consider the methods that share these commonalities: gathering stakeholder opinion, developing requirements, refining concepts according to selection criteria, and

[1] It appears to be an application of Category Theory (Eilenberg & Mac Lane, 1945), where the term category for mathematical objects and their natural transformations got confused with Kant's categories as concepts of knowledge (Kant, 1781).

developing a unified prototype. Each method within these constraints has a different focus which can make it more or less appropriate for a chosen CDIO project which we will attempt to describe by explaining how they are used in our curriculum.

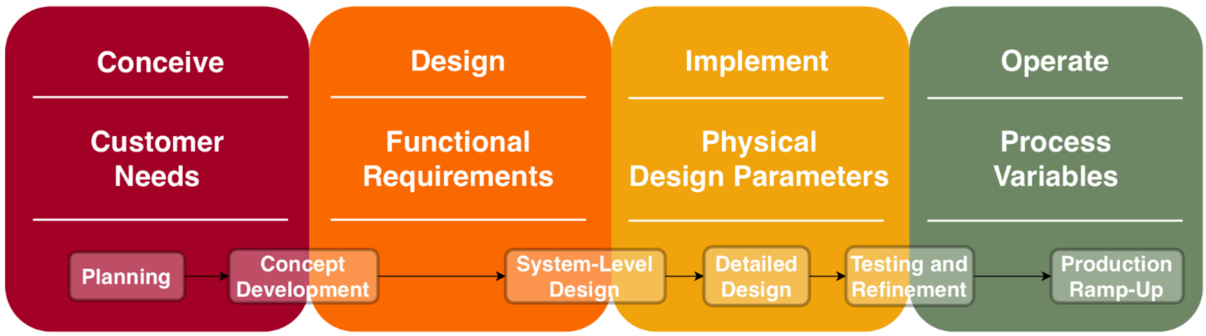

Figure 1. Mapping CDIO stages (top) to Axiomatic Design (middle) and Ulrich et al. (2019) product design process (bottom)

Product Design

The Reykjavik University School of Technology Department of Engineering has been teaching the general product development process as described by Ulrich, Eppinger, and Yang (2019). This book is an industry-standard for product designers considering the end-to-end process of concept to implementation. The general process in Ulrich et al. (2019) is divided into these stages: Planning, Concept Development, System-Level Design, Detail Design, Testing and Refinement, and Production Ramp up. Of note, the Conceive-Design-Implement-Operate stages are inherently incorporated into this framework as shown in Figure 1

The design course curriculum[2] begins with students examining a problem or topic of interest and searching for stakeholders who will become "customers". These customers become an integral part of refining the customer's opinions into "Customer Needs". Based upon these needs, the teams will benchmark existing products to develop competitive metrics and requirements. The requirements give insight into possible concepts, which are explored and refined for the rest of the semester. The deliverable artifacts are often a prototype, presentation, and paper suitable in quality and format for submission to a design conference.

Google Sprint

The Design Sprint was developed by Knapp, Zeratsky, and Kowitz (2016) at Google to design, implement, and evaluate a prototype of a problem solution in five days. Time-limited activities are scheduled each day. Starting from a challenge, a diverse team will work out a solution. On Monday, the team agrees on the goal and creates a map leading customers and other stakeholders towards the solution. The team consults with experts, collects problems, and selects a target, on that the sprint will focus. On Tuesday, the team collects old and new solution ideas to remix them and improve on them. The result of that day will be detailed solutions. On Wednesday, the team selects the best solution and makes a plan for the prototype. On Thursday, the team will create a prototype, or if that takes too much time or

[2] which will become a requirement for all engineering lines in 2022

effort, it creates a façade. On Friday, the prototype will be tested on five customers. The feedback will be used to plan the next steps.

The design sprint is not intended to be a complete design method. It is rather used to reduce the risk of bringing a new product to the market. It is inspired by design thinking (Asimow, 1962) and focuses on the user experience. The method may be used for other design tasks but will need to be adapted. Indeed, prototyping a product in one day limits its use.

Axiomatic Design

Axiomatic Design, developed by MIT Professor Nam Pyo Suh in the 1980's[3] also describes the design process as mapping but at a conceptual level, rather than a temporal one. As previously mentioned, this is a process focused on the mapping between domains. These domains (listed below) have a clear mapping to the CDIO framework as shown in Figure 1: Customer Needs, Functional Requirements, (Design) Parameters, Process Variables. Axiomatic Design has two Axioms which are believed to be inherent in all "good" design (Suh, 2001);

Independence Axiom: Maintain the independence of the Functional Requirements
Information Axiom: Minimize the information content of the design.

These can be translated into a less technical definition as:

Independence Axiom': Modular: minimize interference between requirements
Information Axiom': Robust: Choose implementations that maximize chances of meeting requirements

The general process is to develop a list of up to 7 elements in a domain, then move to map those elements to new elements in the next domain. Axiomatic Design desires solution-agnostic Functional Requirements which allow for further creativity. A customer need (CN) such as "keep my roof attached to my house" might become the functional requirement (FR) "bond roofing material to rafters" which would be mapped to "polyurethane-based glue applied to both surfaces" resulting in a process variable (PV) "Minimum curing of 24 hours at 25 degrees Celsius". At each stage of the mapping, interactions *i.e.* couplings between the mappings must be examined: the optimal configuration is that each functional requirement is only affected by one design parameter as described by the Independence Axiom. Coupling is evaluated by making a Cartesian product of each domain element's transfer coefficient in a matrix called a Design Matrix. This matrix gives a simple mathematical expression that can be evaluated for the degree and type of coupling. See (Suh, 2001) for a more detailed discussion of analyzing design matrices.

HYBRID DESIGN METHODS

As mentioned previously, design methods are not necessarily a tool to be used in isolation. We provide in this section adaptations of the previous methods for new environments particularly cross-disciplinary.

[3] Conceived at Burger King in Cambridge Massachusetts

Collective System Design

While David Cochran was at MIT, he was exposed to Axiomatic Design and wished to spread the innovative way of thinking to fields such as automotive manufacturing. Unfortunately, the technical nature of how it is described the taught is daunting to the average management or non-engineer. He decided to take the basic concepts of Axiomatic Design and make them more approachable to a non-technical manufacturing audience which resulted in the creation of the Manufacturing System Design Decomposition (Cochran, Foley, & Bi, 2016; Suh, Cochran, & Lima, 1998) leading to the more general Collective System Design process (Cochran, Smith, Sereno, Aldrich, & Highly, 2019). In the new system, Design Parameters became Problem Solutions. Both Functional Requirements and Problem Solutions have a metric that is used as an explicit test and/or target. He also realized that the design matrix was very hard for many people to intuitively understand, so instead, a tree structure is used to encode the same information. The final touch was to put the process in the context of a “Flame model” that sets the tone of why design is important as a collective agreement: 1. Standard work/actions 2. Structure 3. Thinking 4. Tone. In the collective system design process, diagnosis starts with standard work and drills down to the tone (1 → 4). At this point, the management of the organization makes a “conscious choice to change” involving workers at all levels. The design phase begins with this tone and works its way back to standard work (4 → 1).

This new “view” on Axiomatic Design has gained much traction in the automotive manufacturing industry as a method for becoming more “lean” Cochran et al. (2019) and is an alternative to the INCOSE Systems Engineering process (INCOSE, 2015).

ADAPT: Axiomatic Design and Agile

In 2017, Jakob Weber and his team at Daimler AG (Mercedes-Benz Research and Development) began to adopt Axiomatic Design in a format that made more sense for how they designed automotive manufacturing in a “turbulent setting”[4]. They noticed that Axiomatic Design provided a top-level strategy for high-level goals in a research manufacturing project but did not indicate how to arrange the tasks and work. There was a realization that this missing component can easily be filled by Agile methods such as SCRUM. In the new method Weber, Förster, Stäbler, and Paetzold (2017) described, Axiomatic Design would first identify the design opportunities and implementation goals, then these Functional Requirement-Design Parameter pairings would become tasks for the product backlog. After a SCRUM had been completed, the information (and incomplete tasks) would be refactored into the FR-DP mappings to build a new design matrix (or design decomposition) and the cycle would continue. Joining these two provided a very useful guideline for Axiomatic Design: the right amount of decomposition is when an FR-DP pairing is a task that can be approached during a SCRUM period with an educated guess of its completion time. ADAPT became successful enough that additional enhancements were implemented including modularity indexing for sequencing and priorization (Kujawa, Weber, Puik, & Paetzold, 2018).

Google Sprint and Axiomatic Design

In the academic year 2019, the two authors have taught the course “Introduction to Internet of Things and Embedded Systems” together. This course integrates the design of Things

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[4] Previously they had done so in small projects, but it had not gained widespread interest within the company (Weber, Förster, Kößler, & Paetzold, 2015)

(embedded devices) with the design of software systems (connecting Things through the internet). This course also required integrating design methods as well: mechatronics students had previously learned about Axiomatic Design, while students of computer science and software engineering were only familiar with agile methods.

The authors discovered that while both methods have different origins, they work well together. The Sprint method provided stream-lined methods to explore the customer domain and the functional domain, while Axiomatic Design helped in structuring the requirements and building the prototype.

APPLICATION OF DESIGN SELECTION

Internet of Things Class

During the last four years, the second author taught a course on designing Internet of Thing (IoT) applications to computer science and software engineering students at Reykjavik University. The class is taught as a three-week block, in which the first week is devoted to examples of IoT, catching up on embedded programming practices, and the study of network protocols used in IoT systems. During the second week, students design an IoT system. During the third week, that design is prototyped and evaluated. Applications ranged from control systems for cooking sous vide to network-connected picture frames and smart food containers. During the term 2019, the authors taught the course as a cross-disciplinary course to students of mechatronics, computer science, and software engineering. The students that took the class learned different design methods in previous courses.

The authors have used the Google Design Sprint (see Section “Google Sprint” above). It works well to solicit requirements and test the viability of a product or solution. Students of mechanical engineering and mechatronics have had more issues adapting to the sprint because of their different experience and design approach.

Mechatronics

The inherent multi-disciplinary nature of Mechatronics[5] means that techniques from software, electronics, and mechanical engineering must be considered. For the last four years, the first author has been teaching a short introduction to Axiomatic Design as part of the course. Similar to the experience in the IoT class, this technique has resonated with students with a mechanical engineering competency, but often software-facing students do not understand the need for a formal process. These students would prefer a more Agile-style environment where there is an iterative rapid-prototyping mindset rather than trying to formalize a concept and requirements initially. The second author is considering a hybrid AD-SCRUM design method to satisfy both groups, similar to the ADAPT method developed by Weber et al. (2017).

[5] Often called embedded control systems or robotics in other curricula

CONCLUSION

The CDIO standard gives a great deal of freedom in implementing a practical hands-on education style, particularly in the design area. With such a large realm of possibilities, it is comforting for both the educator and student to have standardized methods to employ. We have presented several generic design methods that we have found applicable in a large variety of student projects and labs. The methods share the same general idea of mapping an ethereal concept into a more concrete simulation or prototype that can then be evaluated and improved. Often the methods are optimized for a particular discipline such as mechanical engineering or software development. In multidisciplinary teams, the one-size-fits-all approach of the "generic" design method does not fit. A better approach was to mix the two design methods by realizing that they are different views of the same general process and educating the students about this universality. The need for this adaptation is present in large manufacturing industries demonstrated by the deployment of ADAPT at Mercedes-Benz's Research and Development department (Kujawa et al., 2018). To conclude, there is no one clear D for *all* Design, but we believe the methods presented are a reasonable place to start.

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AN INNOVATIVE APPROACH TO INTERDISCIPLINARY EDUCATION THROUGH DOMAIN SECTOR COURSES

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ABSTRACT

This paper outlines a framework for interdisciplinary education through domain Sector Courses. The respective set of industrial Sector Courses is conducted at the Skolkovo Institute of Science and Technology (Skoltech). The proposed framework is based on a holistic approach to an industrial sector, considering it with multiple lenses, including technology, business and policy, which provide an interdisciplinary content fundamental to the teaching of innovation. The core idea of a Sector Course is to build a holistic knowledge about a given economic sector and its main actors. In this paper we discuss three examples of the courses offered at Skoltech: a Space Sector Course (Menshenin et al., 2020), a Power Markets Course and a Product Development and Manufacturing Course. All of these courses are called "Sector Courses" taught for graduate-level students and are built upon the CDIO framework (Crawley et al., 2014; Crawley et al., 2013), integrating its standards to support students' knowledge and skills. We discuss the general approach to building the Syllabus and learning environment in these courses and how these are realized through the CDIO framework. We also describe what elements of the courses are essential and how – when combined together – they lead to the specific set of learning outcomes of such courses. The practical utility of the proposed paper is that it outlines the core principles of the economic sector courses based on the CDIO approach. Such principles allow the systems educators to build a Sector Course in any domain of interest, facilitating the students' knowledge and skills development to foster innovation.

KEYWORDS

Innovation, entrepreneurship, interdisciplinary thinking, systems thinking, critical thinking, Standards: 1, 2, 7, 8

INTRODUCTION

This paper outlines the framework for interdisciplinary engineering education through the domain Sector Courses. Such courses are aimed to cover a specific industrial sector by providing a holistic view of it from a variety of the engineering and business viewpoints. We base our discussion on three Sector Courses offered at the Skolkovo Institute of Science and Technology (Skoltech): the Space Sector Course (SSC) (Menshenin et al., 2020), the Power Markets Course, and the Product Development and Manufacturing Course. These are regular university courses taught for graduate-level students and built upon the CDIO framework (Crawley et al., 2014; Crawley et al., 2013), integrating its standards to support students' knowledge and skills acquisition. These courses are M.Sc. and PhD levels courses worth 6

ECTS and taught at Skoltech in the English language. The Space Sector Course that is considered in this paper in detail is a compulsory course for the students in the Space and Engineering Program, which is one of the official programs for graduate level students at Skoltech.

The objective of our paper is to present a general framework for the Sector Courses in any domain of interest. Such a framework aims to specify what are the core elements of the course and how – when combined together – these elements lead to specific learning outcomes for this type of course. We discuss one of the courses, the Space Sector Course, in detail as a case study. The practical utility of our paper is that it outlines the core principles of the Sector Courses based on the CDIO approach. We also present the architecture of one the courses using the Cloud-based OPCloud modeling environment (Dori et al., 2019), which provides a good synthetic view of the components and architecture of the course.

Sector Course Definition

A "Sector Course" is designed to provide a holistic content of an industrial sector, considering it with multiple lenses, including technology, business and policy, which provide an interdisciplinary perspective, fundamental to the learning of innovation. The core idea of a Sector Course is thus for the students to develop a more holistic knowledge about a given economic sector: its actors, its priorities, its technological, economic and societal challenges, its history.

"Holistic" Approach to Engineering and Business

The emphasis of such a course is thus placed on the breath of the content by inviting various actors to present their specific point of view and by giving the students an opportunity to reflect on the integration of these various points of view. Critical thinking can play a vital role in such a course because it provides useful tools for the students to study the various points of view presented from a number of media sources. This allows them to deepen their understanding of the given economic sector and open their mindset to how they could possibly become proactive actors in this domain.

Innovation and entrepreneurship have become an important learning outcome in the extended CDIO Syllabus 2.0 (Crawley et al., 2011) and also in some of the highly recognized engineering programs such as MIT, SUTD, UCL and Chalmers as reported by Graham (2018). To implement these advanced learning outcomes concrete content and learning experiences must be integrated into the curriculum to reach these goals. The approach of the Industrial Sector Courses is such a concrete mean to implement the innovation and entrepreneurship in a curriculum.

Skolkovo Institute of Science and Technology (Skoltech)

Skoltech is a Moscow-based university that was founded in 2011 in collaboration with MIT. It offers the graduate programs in a variety of disciplines – from space and energy to biomedicine and IT. From the very beginning of its existence, Skoltech has been actively developing its courses following the CDIO approach (Crawley et al., 2014).

Skoltech is broadly recruiting the graduate-level students from different disciplines related to science and engineering. Skoltech is primarily focusing on searching for students who have a solid fundamental background and are motivated to bring together science and technology &

entrepreneurship and innovation. All students are receiving scholarships and are studying in the English language.

In our paper we discuss the key aspects and takeaways of the application of the CDIO principles to Sector Courses at Skoltech.

OVERVIEW OF SECTOR COURSES

Our paper is based on the experience with running three courses offered at Skoltech: The Space Sector Course (SSC) (around 120 students completed the course since 2014), the Power Markets Course (around 70 students completed the course since 2014) and the Product Development and Manufacturing Course (around 25 students completed the course in 2015). The detailed courses descriptions are outlined in Table 1.

In our paper we discuss in detail the SSC as a Case Study in the next section, yet we argue that the principles of the Sector Courses remain the same regardless of the field. Thus, the proposed approach could certainly be used for other sectors of engineering education.

Table 1. Sector Courses Descriptions

Course Name	Course Description
Space Sector Course (SSC)	This course examines the domain of space from multiple vantage points — space as a business, a way of life, a fulfillment of human dreams. In addition, it examines space-related issues that drive key international regulatory, economic, and global policy. To gain insight into these different dimensions, we examine space through three different lenses: sub-sectors, technologies, and organizations.
Power Markets Course	The course will introduce the students to power system economics. After covering the fundamentals of microeconomics, the main types of electricity markets and regulations will be discussed including the Russian market. Economic dispatch and Optimal Power Flow with Locational Marginal Pricing will be covered. Capacity planning, ancillary services, and risk analysis are also covered. The lectures will be supplemented by homeworks utilizing the PowerWorld simulation package, including laboratory exercises investigating gaming in power markets and group mini-projects.
Design and Manufacturing Sector Course	This course introduces students to the global process and business side of the Product Design and Manufacturing sector and provides an overview of various types of products/manufacturing systems. The course includes a seminar series from manufacturing sector executives and other key stakeholders from industry and research organizations. Topics covered include: overview of design and manufacturing, product development overview, global perspective of manufacturing systems, business overview of a few manufacturing sub-sectors like space, automotive, aerospace, space, heavy equipment and others.

The three courses presented above have essentially the same objective, which is to develop, for the students concrete means to integrate technology and business perspectives in order to open for them new avenues of development for their career. However, there exist some differences in the approach for each. The Space Sector Course is strongly aligned on the Systems Thinking approach which is a very important component of this business sector; the Power Markets Sector Course also combines technology and business perspectives but offers to the students the opportunity to simulate the negotiations in power markets which is an essential element in this domain. The Design and Manufacturing Sector Course covers effectively a number of industrial sectors and aims to develop for the students an overall view of the technologies and systems involved for the design and manufacturing of concrete products as well as give them some understanding of the critical business processes involved in both product development and the physical product realization.

In order to support students in carrying out the assignments and capturing a holistic picture by applying the systemic view on the entire industrial sector, the Course Instructors conduct a number of workshops related to the assignments preparation.

CASE STUDY: SPACE SECTOR COURSE (SSC)

Syllabus

The Syllabus of the SSC examines the space sector through three different lenses: sub-sectors, technologies, and organizations. Such an approach is supported by different lectures, for example, on Earth Observation and geodesy; Launch services and markets; Space science payloads and missions; Space Policy; Space Sector Agencies, Organizations and Plans; “New Space”; Space Robotics; and others. Figure 1 reflects the Space Sector Course in respect to the Skoltech Learning Outcomes Framework (Crawley et al., 2013) built on the CDIO principles. This Framework places a much more important focus on the Leadership in Innovation at the postgraduate level, which is at the heart of the existence of Skoltech. The general Framework is built on the four UNESCO pillars and fundamental dimensions of learning.

The Framework presented in Figure 1 has four key topics and their subtopics. The SSC covers such subtopics as (see Figure 1):

- Knowledge of innovation and entrepreneurship (subtopic 1.3)
- Interdisciplinary thinking, knowledge structure and integration (subtopic 1.4)
- Cognition and modes of reasoning (subtopic 2.1)
- Attitudes and learning (subtopic 2.2)
- Relating to others - communication and collaboration (entire topic 3)
- Making sense of global societal, environmental and business context (subtopic 4.1)
- Visioning - invention new technologies through research (subtopic 4.2)
- Delivering on the vision - entrepreneurship and enterprise (subtopic 4.5)

The content of SSC reflects on the need to meet each learning outcome indicated above and in Figure 1.

According to Crawley et al., “system is a set of elements or entities, and their relationships, whose functionality is greater than the sum of the individual entities” (Crawley et al., 2015). In our paper we apply this definition to consider the Space Sector “holistically” as the system. We first outline the elements (or entities) of the Course. At the next step we define the relationships among these elements. After this we explain how the sum of these individual entities and the relationships between them brings the value delivered through SSC – acquiring the learning outcomes highlighted in Figure 1.

1. DISCIPLINARY KNOWLEDGE AND REASONING

UNESCO PILLAR: LEARNING TO KNOW

1.1 KNOWLEDGE OF MATHEMATICS AND SCIENCES

1.2 KNOWLEDGE OF APPLIED SCIENCE AND ENGINEERING SCIENCE

1.3 KNOWLEDGE OF INNOVATION AND ENTREPRENEURSHIP

1.4 INTERDISCIPLINARY THINKING, KNOWLEDGE STRUCTURE AND INTEGRATION

1.5 KNOWLEDGE AND USE OF CONTEMPORARY METHODS AND TOOLS

2. PERSONAL ATTRIBUTES – THINKING, BELIEFS AND VALUES

UNESCO PILLAR: LEARNING TO BE

2.1 COGNITION AND MODES OF REASONING
- Analytical reasoning and problem solving
- System thinking
- Creative thinking
- Decision making (with ambiguity, urgency etc)
- Critical thinking and meta-cognition

2.2 ATTITUDES AND LEARNING
- Initiative and the willingness to take appropriate risks
- Willingness to make decisions in the face of uncertainty
- Responsibility, intensity, perseverance, urgency and will to deliver
- Resourcefulness, flexibility and an ability to adapt
- Self-awareness and a commitment to self-improvement, lifelong learning and educating

2.3 ETHICS, EQUITY AND OTHER RESPONSIBILITIES
- Ethical action, integrity and courage
- Social responsibility
- Equity and diversity
- Trust and loyalty
- Proactive vision and intention in life

3. RELATING TO OTHERS – COMMUNICATION AND COLLABORATION

UNESCO PILLAR: LEARNING TO WORK WITH OTHERS

3.1 COMMUNICATIONS
- Communications strategy and structure
- Written, electronic and graphical communication
- Oral presentation and discussion
- Inquiry, listening and dialogue

3.2 COMMUNICATIONS IN INTERNATIONAL ENVIRONMENTS
- Communications in English in scientific, business and social settings
- Effective interaction in different cultural and international settings

3.3 TEAMWORK
- Forming effective teams
- Team operations and project management
- Team coordination, decision-making and leadership
- Team growth and evolution
- Technical and multidisciplinary teaming

3.4 COLLABORATION AND CHANGE
- Establishing diverse connections and networking
- Appreciating different roles, perspectives and interests
- Negotiation and conflict resolution
- Advocacy
- Bringing about intentional change

4. LEADING THE INNOVATION PROCESS

UNESCO PILLAR: LEARNING TO DO

4.1 MAKING SENSE OF GLOBAL SOCIETAL, ENVIRONMENTAL AND BUSINESS CONTEXT
- Appreciating the potential and limitations of science and technology, their role in society and society's role in their evolution
- Taking responsibility for sustainable development, including social, economic, environmental and work environment aspects
- Understanding the technical products, systems and infrastructure of the sector
- Understanding the enterprise – culture, stakeholders, strategy and goals
- Understanding the business context – markets, policy and ecosystem of the sector

4.2 VISIONING – INVENTING NEW TECHNOLOGIES THROUGH RESEARCH
- The research process – hypothesis, evidence and defense
- Basic research leading to new scientific discovery
- Research aimed at developing new technologies
- Imagining utility of new science and technology
- Developing concepts and reducing to practice

4.3 VISIONING – CONCEIVING AND DESIGNING SUSTAINABLE SYSTEMS
- Identifying stakeholders need and wants
- Identifying and formulating objectives and goals
- Conceiving and architecting products and services around new technologies and identifying their impact
- Disciplinary and multidisciplinary design for sustainability, safety, aesthetics, operability and other objectives
- Understanding the technical context and ecosystem of the product or service
- Design process management, including planning, project judgment and effective decision-making

4.4 DELIVERING ON THE VISION – IMPLEMENTING AND OPERATING
- Designing and optimizing sustainable and safe implementation and operations
- Manufacturing and supply chain operations
- Supporting the system life cycle including evolution and disposal
- Implementation and operations management

4.5 DELIVERING ON THE VISION – ENTREPRENEURSHIP AND ENTERPRISE
- New venture conceptualization and creation
- Financing product development and new ventures
- Building and leading an organization and extended organization
- Initiating engineering and development processes
- Selling, marketing and distributing products and services
- Understanding the value chain – the innovation system, networks and infrastructure
- Managing intellectual property and respecting the legal process

Figure 1. Skoltech Learning Outcomes Framework (Crawley et al., 2013)

Besides the domain-specific topics focused on knowledge acquisition, we uncover the skills-based tools, such as system thinking, critical thinking, the economics of a firm, how firms compete and the value chain in the development of a product. These universal skills aim to provide the coherent knowledge acquisition and skills development. For example, the lecture on critical thinking supports the students to properly analyze the content of lectures, videos and documents with a set of well-established criteria. The miniguide on Engineering Reasoning (Paul et al., 2013) is used as a reference in concrete assignments.

Figure 2 summarizes the high-level architecture of the SSC in OPCloud modeling language (Dori et al., 2019). The ultimate goal of the course is to support Students in meeting Learning Outcomes. The process "Acquiring" changes the state of the Learning Outcomes from state "not acquired" to "acquired". The instrument that is used to meet those learning outcomes is the "Space Sector Course" built upon the "CDIO Framework". The utility of the modeling representation is that it allows to comprehensively outline the architecture of the course, and as it will be shown later – to define the core Course's elements and their relationships.

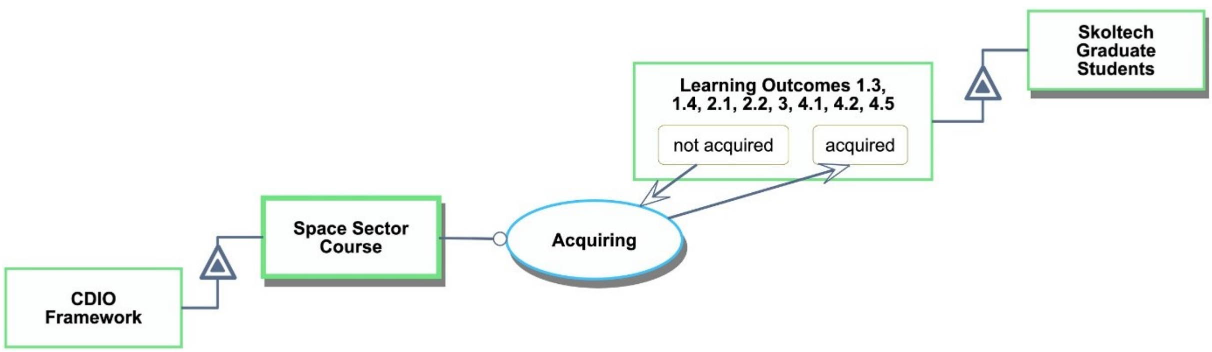

Figure 2. Holistic View of SSC. Rectangles represent objects, such as "Skoltech Graduate Students", "Learning Outcomes" (with the numbers reflecting the specific topics/sub-topics from Figure 1), "Space Sector Course", and "CDIO Framework". An oval denotes a process, for instance, "Acquiring". "Roundtangles" are encoding the states, such as "not acquired" and "acquired". The triangle inside a triangle means that, for example, "Learning Outcomes" is an attribute of "Skoltech Graduate Students" implying that upon completion of SSC the students will acquire the required knowledge and skills.

Elements of SSC

The SSC consists of cross-disciplinary lectures (such as Critical Thinking Lecture, System Thinking Lecture, Economics of a Firm, and Value Chain Analysis as specified in Figure 3), sectoral lectures (for example, Space Sector Agencies and Organizations, Launch Services and Markets, and Space Science), and assignments (Assignment 1: System Map, Assignment 2: Critical Thinking's Lecture Analysis, Assignment 3: Business Plan Analysis). Note that the elements appearing in Figure 3 are representative and are not completely demonstrating the full set of lectures and assignments within the SSC.

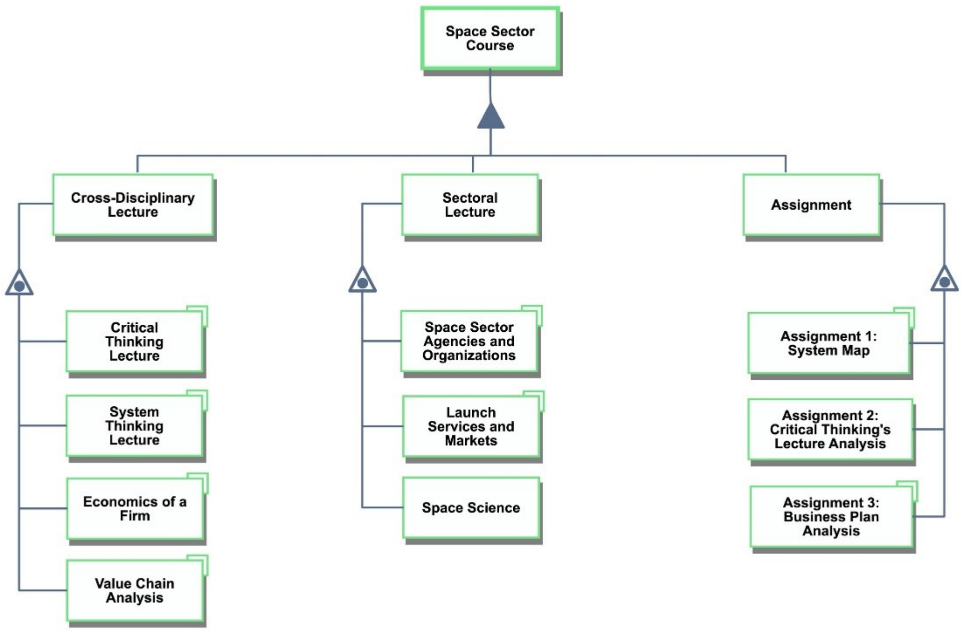

Figure 3. The SSC and its elements: cross-disciplinary lectures, sectoral lectures, and assignments

Relationships among and within the elements of the SSC

Figure 4 represents the relationships between the elements (cross-disciplinary and sectoral lectures and assignments) of the SSC. For example, the left-hand side of Figure 4 informs that Assignment 1 is dedicated to System Map. This Assignment is using the information from the sectoral (Space Sector Agencies and Organizations) and cross-disciplinary lectures (Critical Thinking lecture and System Thinking lecture). All of these lectures are held before the Assignment 1. In the same manner, the cross-disciplinary lectures on Economics of a Firm and Value Chain Analysis, as well as the sectoral lecture on Launch Services and Markets are all used to support the students with the Assignment 3 dedicated to the Business Plan Analysis.

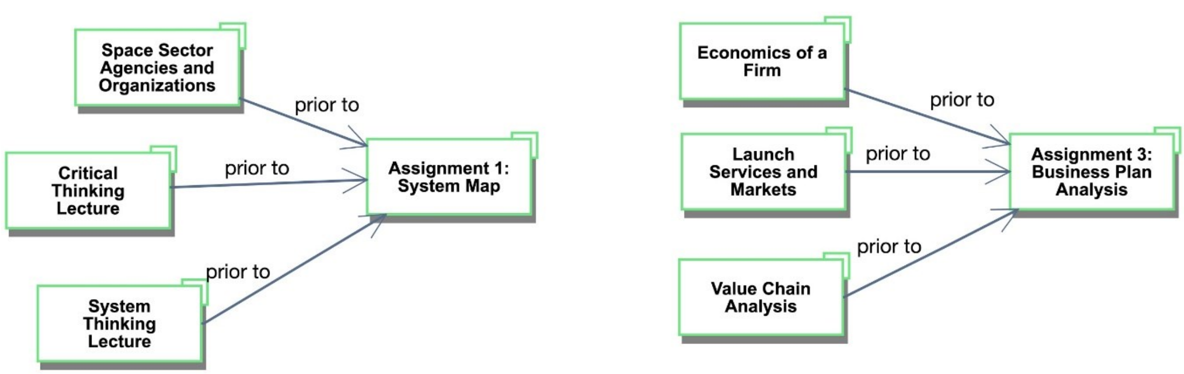

Figure 4. Example of the relationships between the elements of the SSC

DISCUSSION

During more than 5 years of successful implementation at Skoltech, the SSC proved itself as a practical and useful course for graduate-level students. The course has been held 5 times and was delivered for more than 120 students at Skoltech. The SSC was once held in parallel with MIT class (16.S899 in 2017) in the AeroAstro Department. This has led to joint collaborative work of students followed classes at Skoltech and at MIT.

Upon completion of the Course, students are exploring and proposing concrete entrepreneurial projects – either hardware or software start-up projects. Over the course of the Class, students have presented around 50 projects, around 10% of which became entrepreneurial ventures after the successful completion of the Class.

A practical utility of the SSC and any other Sector Course at Skoltech is that they help students to shape a holistic understanding of a number of sector-related questions. Among such questions are "Who are the main stakeholders in this sector?"; "How profit is achieved in this sector?"; "Which resources are critical for each stakeholder and how the process of resources' exchange is organized?", "Who are the most successful commercial actors in this sector?"

Skoltech recruits students broadly, from multiple disciplines related to science and technology. In light of this, a Sector Course is a unique perspective to support students in acquiring knowledge and skills related to a whole sector's lifecycle. In this capacity a Sector Course reflects Standard 1 (the context) of the CDIO Standards 3.0. SSC is also aiming at achieving the specified learning outcomes, thus, covering the Standard 2 (learning outcomes) of the CDIO Standards 3.0. The students are using the acquired knowledge and skills to propose the commercially viable project at the end of the course. This involves the consideration of the proposed project from a variety of disciplines – not only purely engineering, but also economical and societal ones. All of these support Standard 7 (integrated learning experiences). In accordance with Standard 8, students are also asked to assess the lectures of stakeholders based on the principle of critical thinking and they also have to develop a project of their own in teams based on the content of the course.

In our paper we explore the experience of running the SSC at Skoltech. We have chosen this course (out of 2 others – Power Markets Course and Design and Manufacturing Sector Course), because it was conducted more often than the other two.

CONCLUSION

This paper discusses a general framework for a particular type of course which we call a Sector Course in any domain of interest. To develop such a framework, three courses run at Skoltech were overviewed: Space Sector Course, Power Markets Course, and Product Development and Manufacturing Course. As a case study, the Space Sector Course has been chosen and described in detail. We covered the syllabus, lectures/seminars, and the relationships among and within these elements aiming at shaping students' knowledge and skills in accordance with the CDIO approach. Key learning outcomes from the Course are concerned with the students' ability to capture the entire sector, by acquiring the knowledge required for the integration of engineering and business perspectives of the Space sector. On the one hand, this process meets the Skoltech learning outcomes framework. On the other hand, it leads to a very practical outcome, as the students start to see potential employers, or potential fields for new startups.

One of the main issues to develop such a Course is to be able to invite a wide variety of specialists from the field, who can provide from their combined contributions a global perspective on an industrial sector. Another issue is that there should be proper interaction between the Course Instructors and invited guest lecturers. This is important to facilitate the alignment of their lecture with the global systemic framework.

Upon successful completion of the Sector Course, the students acquire the knowledge and professional skills required to consider innovation and entrepreneurial paths for their careers. This is achieved through different channels, among which are: holistic view of the Sector and integration of the lectures and assignments. We also try to invite guest lecturers, who are alumni of this Course and have founded and/or are currently working on a Space-related startup.

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EXPERIENCES FROM APPLYING THE CDIO STANDARD FOR SUSTAINABLE DEVELOPMENT IN INSTITUTION-WIDE PROGRAM EVALUATIONS

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ABSTRACT

In the CDIO standards 3.0, the original "core" CDIO standards have been updated regarding sustainable development. In addition, one of the new, so called "optional", CDIO standards addresses sustainable development. This paper puts the new CDIO standard for sustainable development to test, in an institution-wide evaluation of engineering education programs at the KTH Royal Institute of Technology. First, the standard is operationalized by establishing a set of indicators and slightly modifying the standard rubrics. Then, it is used in the evaluation of a large number of programs on bachelor and master level. Examples are given of the evaluation outcomes, and the character of the integration of sustainable development in programs on different rubric levels are discussed. With the proposed indicators and rubric modifications, the new standard is concluded to be a useful tool for evaluating, promoting, and guiding, integration of sustainable development, not only in programs with particularly high ambitions regarding sustainable development, but in basically any engineering program. It is recommended that the new standard, with the here proposed modifications, is used for setting university-wide goals and for providing teachers and program directors with a framework for enhancing the future relevance of engineering education programs.

KEYWORDS

Engineering education for sustainable development, Program evaluation, Optional standard for sustainable development, Standards: 1-12

INTRODUCTION

The CDIO standards 3.0 comprises updates to the 12 CDIO standards together with the introduction of "optional" standards, one of which refers to integration of sustainable development in engineering programs. When the new standards were first presented, the CDIO community was encouraged "*to document the work and share their experiences, in particular reflecting on the usefulness of the new standards for future refinement and development*" (Malmqvist et al., 2020a). The objective of this paper is, accordingly, to analyse the first experiences of using the new CDIO standard for sustainable development in institution-wide program evaluations at the KTH Royal Institute of Technology. In the process of evaluating the integration of sustainable development within nearly one hundred engineering programs, the standard has been operationalized and developed in further detail.

The paper is structured as follows. First, the new standard for sustainable development is presented as it was established in 2020 (Malmqvist et al., 2020a). Next, we briefly present the national and institutional context for integration of sustainable development in engineering education at KTH, and the institution-wide evaluation of programs. Thereafter follows a section describing how the new CDIO standard for sustainable development was refined and operationalized, to better capture conceptual distinctions as well as essential differences in how programs had implemented sustainable development. The results of the evaluation are illustrated with 15 programs as examples. Finally, we analyse these experiences and formulate recommendations on how to update and apply the standard.

THE NEW CDIO STANDARD FOR SUSTAINABLE DEVELOPMENT

The CDIO standards were first formulated in 2004 (CDIO 2004) and presented more extensively in Crawley et al. (2007). They define the distinguishing features of CDIO programs in terms of a set of principles and good practices concerning: engineering education philosophy and aims (Standard 1); curriculum development (Standards 2, 3, 4); engineering projects and workspaces (Standards 5, 6); teaching and learning methods (Standards 7, 8); faculty development (Standards 9, 10); and assessment and evaluation (Standards 11, 12). The standards are intended to serve as guidelines for educational reform, enable benchmarking with other CDIO programs, and provide a tool for self-evaluation-based continuous improvements.

In 2014 and 2016, minor modifications resulted in the CDIO standards 2.0 (Crawley et al., 2014) and 2.1 (Bennedsen et al., 2016). In 2017, Malmqvist et al. (2017) pointed out needs for more extensive updating of the standards to account for a number of education change drivers, both external and internal within the CDIO Initiative. This eventually resulted in the CDIO standards_3.0, where the original twelve, now called "core", CDIO standards have been substantially updated (Malmqvist et al., 2020b) and also complemented with so called "optional" CDIO standards that codify additional educational good practices that have been developed within the CDIO community (Malmqvist et al., 2020a).

One of the major change drivers, motivating and guiding the updating of the standards, has been the recognition that engineering education plays a critical role in the urgent societal transformations that are needed for ensuring a healthy planet and sustainable living conditions for ourselves as well as for future generations (e.g. NAE, 2008; Enelund et al., 2013; UN, 2015; UNESCO, 2017). The importance of and focus on sustainability and sustainable development has therefore been emphasized in several of the updated twelve "core" CDIO standards. For example, in Standard 1 the word "sustainable" has been added in the characterization (*Adoption of the principle that <u>sustainable</u> product, process, system, and service lifecycle development and deployment … are the context for engineering education*), and in the description of Standard 1 environmental, social, and economic sustainability are expressed to be considered as integral aspects throughout the lifecycle (Malmqvist et al., 2020b). Sustainable development is hereby from now on explicitly an integral part of the CDIO concept. To further emphasize the role of sustainable development, and to provide goals and guidance for programs with particularly high ambitions, one of the new "optional" CDIO standards addresses sustainable development (Malmqvist et al., 2020a).

In Box 1-4 below, this new CDIO standard for sustainable development – hereafter referred to as '*the SD standard'* – is reproduced as it was established (Malmqvist et al., 2020a). It follows the same format as all CDIO standards and is formulated in terms of: a characterization; a description; a motivating rationale; and rubrics for self-evaluation.

As seen in the description in Box 2, the SD standard is formulated with direct reference to the twelve “core” standards, pointing out how the central aspects of the “core” standards should be complemented with elements from the education for sustainable development domain (ESD), such as *interdisciplinarity and transdisciplinarity*, *transformative learning*, and *key competences for sustainability* (e.g., according to UNESCO 2017). The SD standard can hereby, more than other “optional” or “core” standards, be considered as a kind of meta-standard that guides and has impact on the implementation of all twelve core standards.

The general principles and functions of the CDIO standard rubrics are described by Bennedsen et al. (2014; 2016). As seen in Box 4, the rubrics for the SD standard goes slightly beyond these general principles in that they are more detailed in the description of evidence and indicators for the different rubric levels. This, among other things, will be further elaborated in the following section, where the SD standard is put to test in program evaluations.

Box 1. The SD standard characterization.

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

Box 2. The SD standard description.

The program emphasizes environmental, social and economic sustainability in the adoption of the CDIO principles as the context for engineering education (Standard 1). Sustainability related knowledge, skills and attitudes, are explicitly addressed in program goals and learning outcomes (Standard 2). Aspects of sustainable development are integrated in several mutually supporting disciplinary courses and projects, possibly in combination with specific sustainability courses (Standard 3). Concepts of sustainability, potentials and limitations of science and technology and related roles and responsibilities of engineers, are established at an early stage of the education (Standard 4). Design-implement experiences provide students with opportunities to apply and contextualize sustainability knowledge, skills and attitudes, both in the development of new technology and in the reuse, redesign, recycling, retirement, etc., of existing technology (Standard 5). Physical and digital learning environments enable interdisciplinary and transdisciplinary collaborative learning and interaction with various external stakeholders (Standard 6). Sustainability learning experiences are integrated with the learning of disciplinary knowledge, personal and interpersonal skills, and product, process, system and service building skills (Standard 7). Active experiential and transformative learning activities develop students’ key competences for sustainability (Standard 8). Enhancement of faculty competences for sustainability and related teaching competences is actively promoted (Standard 9 & 10). Approaches appropriate for assessing sustainability related learning outcomes are implemented (Standard 11). The integration of sustainable development is evaluated by students, faculty, industry, and societal stakeholders, and in relation to relevant UN and other frameworks (Standard 12).

Box 3. The SD standard rationale.

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

Box 4. The SD standard rubric.

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

APPLICATION OF THE CDIO STANDARD FOR SUSTAINABLE DEVELOPMENT IN PROGRAM EVALUATIONS AT KTH

Evaluating integration of sustainable development according to national and institutional mandates

According to the Swedish Higher Education Act, Swedish higher education institutions *shall promote sustainable development in their activities, which means that current and future generations are assured of a healthy and good environment, economic and social welfare, and justice*. Further, the Swedish Higher Education Ordinance stipulates overarching learning objectives and degree requirements for all Swedish university degrees. For some degrees, for example the Master of Science in Engineering degree (*civilingenjörsexamen*), there are specific degree requirements regarding sustainable development, whereas some degrees, for example the general Bachelor of Science and Master of Science degrees, do not have degree requirements directly related to sustainable development.

In addition to these national requirements, many universities have formulated their own internal sustainability objectives. For example, in the internal sustainability objectives for education for the period 2016-2020 for the KTH Royal Institute of Technology, it is stated that: *Sustainable development shall be integrated into all educational programs at all levels so that students can contribute to the sustainable development of society after graduation* (KTH). KTH is hereby going beyond the national policies by also requiring integration of sustainable development in the general Bachelor of Science and Master of Science programs and in the third level PhD programs.

The overall KTH approach for considering sustainable development in the engineering education programs is very much in line with the CDIO concept of integrated curriculum (Standard 3), in the meaning that sustainable development should not just be considered as an add-on in some separate courses but instead be interwoven with the learning of disciplinary knowledge and its application in professional engineering. How this should be implemented is however left for the programs to decide but guidelines and support is provided by the KTH Sustainability Office and the KTH Department of Learning.

During 2020, the fulfilment of KTH's sustainability objectives for education for the period 2016-2020 has been evaluated by the KTH Sustainability Office and the KTH Department of Learning in collaboration. Nearly 100 programs on bachelor, master, and doctoral level, were evaluated. Due to the large number of programs, the basis for the evaluation was limited to program objectives and intended learning outcomes stated in the formal program and course documents, together with the yearly program analysis reports that each program director produces as part of the KTH quality assurance procedures. This limits the evaluation, and the results should be interpreted accordingly.

As the SD standard is new since the summer 2020 (Malmqvist et al., 2020a), it has not yet been used to develop the KTH programs. Still, it was decided to apply the new SD standard as one of several instruments in the evaluation of the fulfilment of KTH's sustainability objectives for education for the period 2016-2020.

Operationalizing the SD standard

To facilitate the application of the SD standard in the evaluation of KTH's engineering programs, a number of indicators were established, see Box 5. The indicators relate to different elements in the SD standard description (Box 2) and rubrics (Box 4).

The first indicator (i) considers the extent and character of the program objectives. The Swedish Higher Education Ordinance sustainable development related degree requirements for the Master of Science in Engineering degree (*civilingenjörsexamen*), here reproduced in Box 6, were used as benchmark for all programs (i.e., also for the general Bachelor of Science and Master of Science programs for which the Higher Education Ordinance does not stipulate any specific sustainable development related requirements). The second indicator (ii) considers the introduction to sustainable development at an early stage of the program. This is considered important for building progression through following courses, and also for avoiding that the basic concepts of sustainable development are being repeated again and again through the program.

The three next indicators (iii-v) refer to the number of courses in the program that include learning experiences related to sustainable development. It should be noted that only *compulsory* courses that all students in the program must take, are considered. Just like in the SD standard rubrics (Box 4) distinctions are made between *minor* and *substantial* sustainable development related learning experiences, as well as between courses that are mainly developing students' *knowledge* about sustainable development, and courses that are developing students' *knowledge & skills*, and *key competencies for sustainability*. To facilitate the application of the SD standard in the evaluation of KTH's programs, the meaning of *minor* and *substantial* have here been more clearly defined, see Box 7.

The last indicator (vi) considers the program's development plans and processes as reflected in the program analysis reports. This can for example be plans for integrating sustainable development in more courses, or clarifying and improving progression between courses, or enhancing the teachers' competences.

We note that indicators iii-v can be determined quantitatively whereas indicators i, ii, and vi will have to be judged qualitatively. The feasibility of the indicators will be further explored and discussed below.

Box 5. Proposed indicators for application of the SD standard in program evaluations.

Indicator		Value
i	Sustainable development (SD) related program objectives	0: missing; 1: some; 2: in line with the Swedish Higher Education Ordinance requirements for the Master of Science in Engineering Degree; 3: more extensive/ambitious.
ii	Introduction to SD at an early stage of the program	0: missing; 1: exists; 2: extensive/ambitious.
iii	Number of compulsory courses with minor SD learning experiences	Number
iv	Number of compulsory courses with substantial SD learning experiences that are developing students' knowledge for SD	Number
v	Number of compulsory courses with substantial SD learning experiences that are developing students' knowledge & skills for SD	Number
vi	Development plans & processes	0: missing/unclear; 1: exists; 2: extensive/ambitious.

Box 6. Sustainable development related degree requirements for the MSc in Engineering degree (*civilingenjörsexamen*), as stipulated in the Swedish Higher Education Ordinance.

For the Master of Science in Engineering degree, the student should be able to demonstrate:

- ability to design and develop products, processes and systems with consideration of human prerequisites and needs and the society's goals for economically, socially and ecologically sustainable development;
- ability to formulate judgements considering relevant scientific, societal and ethical aspects, and demonstrate an awareness of ethical aspects on research and development work;
- insight into the possibilities and limitations of technology, its role in society and the responsibility of humans for its use, including social, economic as well as environmental and work environment aspects.

EVALUATION PROCESS AND RESULTS

Testing and calibrating the indicators and rubrics in pilot evaluations

The application of the SD standard in the evaluation of the KTH programs was performed in two steps. First, a pilot was performed with ten selected programs. This confirmed the feasibility and enabled some calibration of the indicators and definitions, described in Box 5-7. As mentioned in the previous section, the SD standard rubrics (Box 4) goes slightly beyond the general CDIO standards rubrics principles, in that they are more detailed in the description of evidence for the different rubric levels. These details were found particularly useful, since they make the rubrics applicable, not only for evaluating program development towards full implementation of the SD standard according to the description (Box 2), but also for evaluating and guiding development of basically any engineering program with whatever ambitions and goals regarding sustainable development.

Based on the experiences from the pilot evaluations, the SD standard rubrics were further elaborated to better capture conceptual distinctions as well as essential differences in how programs are integrating sustainable development. This resulted in the slightly modified set of rubrics in Box 8, where bold text indicates additions/changes in relation to the original formulations in Box 4. Most modifications are calibrations of the number and character (*minor* or *substantial*) of sustainable development learning experiences on the different levels. Also, '*skills*' has been added on level 3 and '*key competencies for sustainability*' has been added to level 4. The motivation for and feasibility of these modifications will be further discussed below.

Box 7. Proposed definitions of some terms and concepts in the SD standard.

Minor vs. *substantial* learning experiences:

- A *minor* sustainable development (SD) learning experience is typically a small SD related module, and related learning outcomes and assessment, integrated in a core engineering course or in a program introductory course, corresponding to about one ECTS credit.
- A *substantial* SD learning experience can either be a course that is more or less completely dedicated to SD, or extensive integration of SD in a core engineering course in terms of several intended learning outcomes and related learning activities and assessment, corresponding to several ECTS credits.

Knowledge, *skills*, and *key competencies* for sustainability:

- The modified rubric level 3 (Box 8) requires substantial SD learning experiences that, in addition to developing students' *SD knowledge*, also develop students' *SD skills*, i.e., abilities to apply and operationalize their SD knowledge in engineering work; evaluate environmental, social and economic impacts; and take action for sustainable development based on such evaluations for example in engineering decision making and engineering design.
- The modified rubric level 4 (Box 8) further requires development of students' *key competencies for sustainability*, for example systems-thinking, critical-thinking, normative competency, and abilities to communicate and collaborate across disciplinary and cultural borders. These competencies are clusters of individual dispositions comprising knowledge, skills, motives, and attitudes, that within the Education for Sustainable Development (ESD) domain are considered necessary for coping with the increasingly diverse and interconnected world and for contributing to sustainable development (e.g., Wiek et al., 2015; UNESCO, 2017; Rosén et al., 2019; Brundiers et al., 2021).

Box 8. The SD standard rubric with proposed modifications (in bold).

0 – There are no sustainable development learning experiences in the program. [No modifications proposed]

1 – Minor sustainable development learning experiences **are** implemented **in at least one course** and needs and opportunities for extended integration of sustainable development have been identified.

2 – At least **two sustainable development learning experiences, where at least one is substantial, are** implemented and there is a plan for extended integration of sustainable development.

3 – There are explicit program goals and intended learning outcomes **considering knowledge as well as skills** related to environmental, social, and economic aspects of sustainability, and **students learning towards these goals and outcomes are supported by** at least **four sustainable development learning experiences, where at least two are substantial**, including an introduction early in the program.

4 – The integration of sustainable development is pervasive, well adapted to the program context, promoting progression of knowledge, skills**, attitudes, and key competencies for sustainability**, and there is documented evidence that students have achieved the related intended learning outcomes.

5 – Sustainable development is fully integrated in accordance with the description in the optional CDIO standard for sustainable development. [No modifications proposed]

Evaluation results

After the pilot phase followed a full evaluation of a large number of first and second level programs using the calibrated indicators and definitions (Box 5-7) and the modified rubrics (Box 8). The evaluation results for 15 programs are shown in Table 1. All these examples are from the first 3 years of Master of Science in Engineering programs (the bachelor part of integrated 5 year or "3+2" programs). The shaded column (second from the right) displays the judged SD standard rubric level, based on the indicator values in the preceding columns. The proximity to the next rubric level is estimated in the rightmost column (0=far from; 1=on the way, 2=close). As seen, all these programs have been judged to be on rubric level 1 or higher, which means that they have all integrated sustainable development (SD) to some extent.

Table 1. Examples of the evaluation outcome for 15 KTH programs.

Program	i) Program objectives (0-3)	ii) Introduction to SD at an early stage of the program (0-2)	iii) Number of compulsory courses with minor SD learning experiences	iv) Number of compulsory courses with substantial SD learning experiences that are developing students' knowledge for SD	v) Number of compulsory courses with substantial SD learning experiences that are developing students' knowledge & skills for SD	vi) Development plans & processes (0-2)	SD standard rubric level (0-5)	Proximity to the next SD standard rubric level (0-2)
A	2	2	6	0	4	0	3	2
B	2	2	4	1	1	0	3	1
C	3	0	5	1	0	0	2	1
D	2	1	4	0	1	0	2	1
E	1	1	1	0	0	2	1	2
F	2	1	1	1	0	2	2	1
G	1	0	0	0	1	1	1	2
H	1	0	1	0	1	1	2	1
I	3	2	2	0	1	0	2	1
J	3	1	3	0	0	0	1	1
K	3	1	3	0	0	2	1	1
L	3	2	3	0	3	2	3	2
M	3	2	1	4	0	2	2	2
N	2	0	1	0	0	1	1	0
O	2	1	3	0	0	1	1	0

Among the programs judged to be on rubric level 1, there are quite some differences in the way SD is integrated. Program G for example has only one, but *substantial*, SD learning experience in terms of a 7.5 ECTS course that is completely dedicated to SD issues and aspects of the core discipline of the program and related professions. Program O has three *minor* SD learning experiences integrated in three different core disciplinary courses. Program E only has one *minor* SD learning experience that is formalized in terms of intended learning outcomes and assessment. In the program analysis report, this program however describes ambitions and plans to enhance several existing SD related learning activities and formalize corresponding intended learning outcomes and assessment. This program is therefore judged to be very close to reach rubric level 2 as indicated in the rightmost column. This situation reflects a general evolution process for many programs, where engaged informal bottom-up initiatives creates informal SD related learning activities which are eventually formalized and then work as drivers for more systematic enhancement and progression of SD learning through the program.

As stated in Box 8, a distinction between rubric levels 1 and 2 is, that to be on level 2 a program must have at least two SD learning experience where at least one is *substantial*. As seen in Table 1, most programs judged to be on level 2 have one *substantial* SD learning experience and one or several *minor* SD learning experiences. The *substantial* SD learning experiences are here typically 6 or 7.5 ECTS courses which are more or less completely dedicated to SD issues and aspects of the core discipline of the program and related professions. In contrast to the other programs on level 2, program M has as many as 4 *substantial* SD learning experiences. The reason why this program is still not judged to be on a higher rubric level, is that all these *substantial* SD learning experiences mainly considers development of the students' *knowledge* about SD, but there are no or limited opportunities for the students to develop *skills* and abilities for actually *doing* SD.

A general observation from the program evaluations is that sustainability-related learning objectives in most courses are formulated in terms of "know", "describe", "explain", "reason about", "define", "discuss", "reflect on", which hence can mainly be categorised as *knowledge & understanding* and to some extent also *values & attitude*. There are therefore obvious needs for many programs to develop courses with learning objectives, and associated learning activities and forms of assessment, which also address *skills* and *abilities to develop and design sustainable products, processes, systems and services*, and also other skills and abilities that can contribute to sustainable development. These needs are reflected by indicator v, and a distinction between rubric levels 2 and 3 is that a program for being judged on level 3 must have *substantial* SD learning experiences that are developing students' *knowledge & skills* for SD (see Box 8). These needs were also the motivation for adding '*skills*' already on level 3 in the here proposed modified SD standard rubrics in Box 8 (compared to the original rubric formulations in Box 4 where 'skills' were not required before level 4). As seen in Table 1, the three programs that are judged to be on level 3 respectively have one, three, and four, *substantial* SD learning experiences that are developing students' *knowledge & skills* for SD. Such courses are typically project-based, or at least includes some kind of project or extensive exercises and assignments, where the students are to apply SD related knowledge and methods in realistic contexts and tasks. To reach rubric levels 4 and 5 will require more extensive implementation of project-based or challenge-driven learning experiences (e.g., Wiek et al., 2014; Högfeldt et al., 2019; Rådberg et al., 2020) that can develop students' key competencies for sustainability. Such learning experiences are currently rare on the bachelor level but found in some master programs.

It should here again be emphasized that this evaluation, and the results in Table 1, are limited in terms of the scope of the documentation that was analysed. Further, the evaluation only considered compulsory courses during the first three years, also excluding the thesis project. We note that the thesis project can provide an excellent opportunity for a student to develop skills and abilities for SD, if appropriately considered in intended learning outcomes, assessment, and grading. Nevertheless, the thesis project is individual, and the evaluation results reflect the educational experience afforded to *all students*. We further note that there are compulsory courses in many programs with more limited and informal awareness building learning activities related to SD and also elective courses with strong formal integration of sustainable development, which are not indicated in this evaluation but nevertheless provide valuable contributions to students' SD learning.

CONCLUSIONS & DISCUSSIONS

The concept of “optional” CDIO standards is new and the role and function of these standards still remains to be explored. However, with the here proposed modifications of the rubrics and the introduced indicators and definitions, a conclusion from this work is that the “optional” CDIO standard for sustainable development is now a useful tool for evaluating the integration of sustainable development in engineering education programs. We have further demonstrated that the SD standard is useful not only for guiding and evaluating program development towards full implementation of the standard, but also for evaluating, promoting, and guiding integration of sustainable development in basically any engineering program.

Integration of sustainable development is crucial for the development of future engineering education (e.g., Gumaelius and Kolmos, 2020). It is often initiated and driven as bottom-up initiatives by engaged teachers and program directors, but it should be emphasized that a key factor for more extensive and systematic integration of sustainable development in higher education institutions is the commitment of top management (e.g., Leal Filho et al, 2017, Lozano et al, 2015). Key aspects are that top management sets goals for the integration of sustainable development and also makes sure that there are mechanisms for following up the extent to which the goals are reached (Finnveden et al, 2019). We suggest that the SD standard can be used for setting university-wide goals. A relevant goal for a technical university could for example be that all engineering programs should reach rubric level 3 (according to the here proposed modified rubrics) and that there should be some programs that reaches levels 4 and 5. By defining the goals in this way and operationalizing the SD standard, teachers and program directors are provided with a framework for dialogue and collaboration on the integration of sustainable development in their programs, and there is also a format for follow-up.

Although the SD standard was developed for engineering education programs, it could probably be applied for education programs in other disciplines as well. This is important since sustainable development needs to be integrated broadly across different disciplines (Finnveden and Schneider, 2019). It is therefore suggested that the SD standard, with the here proposed modifications, should be used and further tested not only by technical universities but also more broadly. This could pave the way for inter- and trans-disciplinary interactions and more fundamental transformations of our educational systems and society.

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STUDENT ENGAGEMENT: A PROPOSED OPTIONAL STANDARD

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ABSTRACT

Education directly affected students' futures. However, the roles of students in the educational process, decision making, and development were generally less than other stakeholders. The paper proposed an optional standard in order to formally and systematically include the student engagement into CDIO framework in four spheres of engagement – (1) the management, (2) provision of education, (3) research, and (4) industry and society at the degree of partnership at least. With this platform, the optional standard would directly support most of the main standards in planning, operation, and development of activities and evaluation.

KEYWORDS

Student Involvement, Operational Implementation, Optional Standard, Standards: 2-12

INTRODUCTION

In engineering education, it was undeniably that industry was a very important stakeholder. The industry routinely directed, or even dictated, the goal and means of education to improve the employability of graduates. In the CDIO, there were many literatures on this topic such as Male et al. (2016) and even a proposal for the Standard on Industrial Engagement (Cheah & Leong, 2018).

Students had been one of, if not the most important, stakeholder in engineering education. The education and experiences that they were given during the university years would directly affect their future accomplishment and professional fulfillment. Yet, their roles in the educational process were usually providing feedbacks on teachings and learning processes. This lack of student engagement had also been raised several times at CDIO meetings and conferences. However, there were all piece-wise and focused on particular topics, especially teaching and learning.

In universities, some lecturers associated student engagement with the participation in classes, projects, learning activities or active learnings. In CDIO-related literatures, the student engagement mostly reinforced this perception. For instance, student engagement was mentioned as an important aspect in CDIO projects (Martín et al., 2016; Song et al., 2017), learning activities (Gommer et al., 2016; Hargreaves, 2016), active learning (Ferreira & Martins, 2016) and learning assessment (Ferreira & Martins, 2016). The CDIO Academy, which were held in parallel to the annual CDIO conferences, also focused on the learning by providing opportunities for teams of international students to solve the provided multidisciplinary challenges (Picas, 2014).

STUDENT ENGAGEMENT

Student engagement referred to a broad range of activities in which students participated with the institution, usually the management, education, research, and communities. Student engagement had been a need-to-have for education because engagement was highly correlated with learning and personal development. There were many comprehensive descriptions of the student engagement such as Trowler (2010), Trowler & Trowler (2010). For practical purposes, there were two components of the student engagement that had to be considered, (1) the sphere or the area of engagement and (2) the degree or level of engagement (Quaye & Harper, 2015; Dunne & Owen, 2013).

While most literatures on student engagement did emphasize student behaviors, teaching practices, learning, and academic performance (Carini et al., 2006; Kahu, 2013), other spheres of engagement could be considered and implemented. There were many spheres of engagement depending on the level of education and disciplinary context. For example, in the medical education (Patricio, 2016), the sphere of engagement was identified as the engagement with (1) the management of the school, including the policy, mission, and vision (structure and process), (2) the provision of the education program (delivery of teaching and assessment), (3) academic community (research program and participation in meetings), and (4) local community and service delivery. Meanwhile, Dunne & Owen (2013) provided an outline which included the (1) responsibility for learning, (2) curriculum design and learning, (3) community and (4) discipline and pedagogical research.

In short, the first component described the field of involvements. For engineering education, the sphere could be interpreted into (1) the institutional management, including the policy, mission, and vision, (2) the provision of the education program, including the curriculum design, learning and assessment, (3) academic and professional development and (4) industry engagement and community services. Examples of each sphere could be model on the ASPIRE sub-criterion in Patricio (2016) with the addition of the inclusion of the peer engagement into the sphere (2) due to the undeniable influences and roles of peers on the student development (Porter, 2006) as well as the fact that collaborative learning and working was inherent in engineering practices. For sphere (3), the professional society and entrepreneurship could be added. For sphere (4), the industry could substitute the healthcare services.

The second component, the degree of engagement (Ashwin & McVitty, 2015), had been classified into (1) consultation in which students were asked for their views on a fixed process, resulting in incremental improvement (2) partnership in which students participated in transforming the process, and (3) leadership in which students created new objects of engagement. The increasing degree of engagement indicated the transfer of power, responsibility, and ownership in education. For this component, the higher degree of engagement indicated more students' power and authority; at least the partnership level is expected.

AN EXAMPLE IN IMPLEMENTATION AND LESSONS

The student engagement implementation in the mechanical engineering program, Chulalongkorn University, Thailand, was guided by the practices in the medical program of the same university which was a recipient of the ASPIRE-to-Excellence award for excellence in student engagement from the Association for Medical Education in Europe (AMEE) in 2015 (Drees & Peters, 2016). The objective of this award was to develop international peer-based criteria to benchmark excellence in medical education rather than using publication and grant data to rank medical schools (Hunt et al., 2018). This concept reflected well with the CDIO standards for engineering education.

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The Faculty of Medicine, Chulalongkorn University, have been very successful in creating the institutional culture and formal framework for student engagement such that the degree of engagement was raised to the leadership level. Medical students were formally included in the governance process; student representatives sat as committee members in the program and various administrative committees. Medical students actively involved in curriculum development, formulating teaching and learning, and proving the effectiveness of such processes with educational research. Students also routinely published and presented their works on their education, e.g., Lumlertgul et al. (2009) and Wongkietkachorn et al. (2014).

For the last three years, the mechanical engineering program employed student engagement activities at the partnership level in the course and program evaluation, curriculum revision, and the extracurricular activities.

For the sphere (1) management, students were represented on administrative committees through the Mechanical Engineering (ME) Club, established from the student body and headed by the class presidents, was used as the channel for devolving power from the program and department. For the extracurricular activities, the ME Club representatives planned the activities and scheduled throughout the academic year with the consultation with the lecturers that oversaw the departmental student affairs. Students were consulted on the direction and development of infrastructure, notably the new common room/workspace within the department. Students was involved in the accreditation processes. The course and project feedback at the end of semesters were included into the twice-yearly faculty evaluation.

For the sphere (2) provision of education which concerned the program management, curriculum development, and learning, the student engagement unit in the ME Club was established with students from all years of study and answered to the program committee for the issues in academic affairs. The regular duty was to organize the dependent course and program conduction review at the end of every semester in which the students organized in the style of an end-of-term party (Figure 1). The results of this review were far more useful than the individual course feedbacks, particularly on the design and project courses (Maneeratana et al., 2017). Besides, the units also acted as the student advisory board on the program conduction and curricular. The formal student engagement platform was also useful for the accreditation process as students were holistically and systematically included as the stakeholder with supporting evidence. In short, results from student engagement activities truly transcended previous practices.

The use of student representatives as proxy was particularly useful for unpleasant issues such as plagiarism and cheating. With strict anonymity under the student interface, real situations and surprising insights could be gained such that better responses could be tailored. In a survey on homework copying, it was found that students could formulate more forthright questions as they could empathize the situations better than lecturers. Other students gave truthful answers to their friends as shown in Figure 2. The results were then used to review assigned works, learning processes and supports as well as communication for mutual understanding.

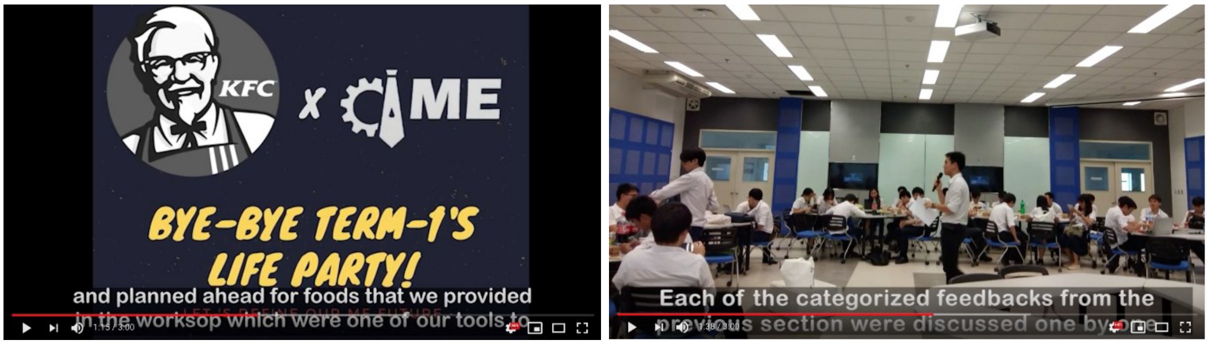

Figure 1. Students' semester program and course review, https://youtu.be/02bwldeXy30.

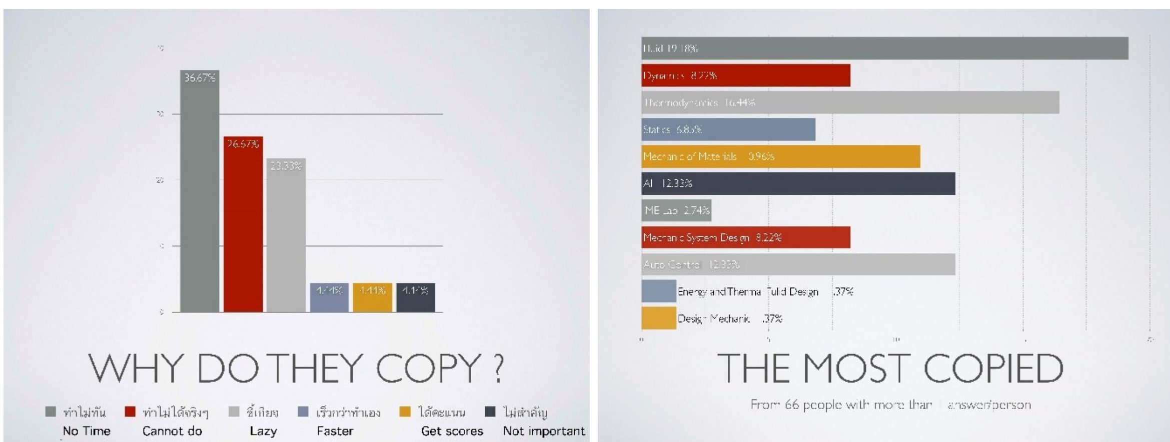

Figure 2. Some results from a students' survey on homework copying behaviors.

Concerning spheres (3) and (4), the ME club plans requested more self-discovery and networking within the student body across the classes, extended and more formal trainings instead of short visits and community services that were directed by students. For instance, there was a community service camp in conjunction with a College of Nursing that students insisted on continuing despite the reluctance from the department due to the complexity and the consumed resources. However, this camp allowed students to determine, direct, and design the contributions, resulting in a much higher sense of satisfaction, fulfillment, actively collaboration across the participating student body, and strong motivation to the junior classes. It was clear that there were shifts in the activities to those that provide more personal fulfillment, and tangible achievements in community services and professional trainings. The style of activities was also changed to be more playful.

It could be summarized that the activities in sphere (1) corresponded with the CDIO Standards 2, 6, 9 and 10. The sphere (2) involved the CDIO standards 3, 8, 11 and 12 as well as Standards 5 and 7 from feedbacks. The sphere (3) involved the CDIO Standards 4. The sphere (4) involved the CDIO Standards 5 and 7.

When the spheres and degrees of engagements were considered, it was found that the component (1) the institutional management as at the consultation level, the (2) provision of education was at the partnership level, the (3) academic and professional was at the partnership level and (4) industry engagement and community services was at the partnership level. With these spheres and degrees in mind, the direction of continuous improvement was clearer.

On the departmental and program management sides, the implementation process was quite difficult due to the conservative institutional and personal culture. There was the real need to change lecturers' mindset on the role of students. For continuous improvement, the inability or inadequacy of the department and program to address the identified problems became a real issue. The surfaced problems had to be properly considered and prioritized for action otherwise the concerned parties would be disappointed and frustrated. Communication with students was the key to mutual understanding; it was normal that few students and lecturers would be particularly active, but all concerned had to achieve the minimum level of engagement and be aware of the ongoing process. The management had to be transparently accountable and perceived to be sincere from the students' viewpoint. All of these involved a change in institutional culture, which was a major challenge by any means.

A PROPOSED OPTIONAL STANDARD

It was recommended that emerging skills and best practices could be incorporated in CDIO as optional standards (Malmqvist et al., 2017). There had been several proposals and under reviewed (Malmqvist et al., 2020). It was noted that there was a student-oriented optional standard, 'Student Success: On the Need for a New Standard' (Gonzales et al., 2018) which placed the importance on the induction, support and retention of students.

The proposed standard came from the combination and adaptation of several standards and practices as well as the context of engineering education, particularly the ASPIRE initiative in medical education (Patricio, 2016) and the methods for enhancing student engagement (Peters et al., 2019).

Concerning the degree of engagement, it was clear that the consultation could only achieve mundane results, which hardly support the promotion of excellence in education. Hence, at least the partnership level was aimed for. Another point that had to be included was the emphasis on the formal platform and institutional structure on the success of the student engagement (Peters et al., 2019).

Optional Standard – Student Engagement

Adoption of the student engagement platform that provided a formal framework for student engagement such that students participated in management, education, professional & research activities and industry & society services in a mutually beneficial collaborative approach with the institutions and programs.

It was noted that the Standards 2-12 involved students' participation in varying degrees. The optional standard proposed a platform that could aid the implementation of these standards in the administrative structure of the program.

Description

The sphere of student engagement composed of the engagement with (1) the management, including the policy, mission, and vision of the department or institution, (2) the provision of the education program, including the teaching, learning activities, peer engagement, assessment and evaluation, (3) disciplinary and professional development, and (4) industry engagement and community services. The degree of involvements was (1) consultation on fixed processes for incremental improvement, (2) partnership which transformed the processes, and (3) leadership with creation of new objects of engagement.

The examples of each sphere in the examples were modeled on the sub-criterion of ASPIRE (Patricio, 2015). An institution could select specific items or formulate details for each sphere of engagement for implementation and specify the degrees of involvement that suited their institution. However, the partnership levels, at least, were recommended for transformative improvement.

Rationale

Students were probably the most important stakeholder in education; their participation in the educational management, processes, and experience had to be made a regular component in education. The student engagement increased learning, intrinsic motivation, as well as students' sense of ownership of the program and achievements. In order to ensure the students' involvement and ownership in their own education as well as provide a framework for supporting student engagement in other CDIO standards, a formal and institutionalized platform which covered desired spheres and engagement degree was needed.

Rubric

Scale	Criteria
5	Student engagement is institutionalized, and becomes a part of the program's continual improvement process with documented evidences of the student engagement platform implementation in all spheres at the partnership degree or above.
4	The student engagement platform is implemented in the program in all desired spheres at the partnership degree or above for at least one year.
3	The student engagement platform is implemented in the program for at least one year.
2	There is an explicit plan to implement the student engagement platform for the program.
1	The need to adopt the student engagement platform in the program is recognized and a process to address it has been initiated.
0	There is no plan to adopt the student engagement platform in the program.

DISCUSSIONS AND CONCLUSIONS

The student engagement had long been presented in CDIO Standards and actual practices. However, it was mostly considered in a narrow aspect of teaching and learning. The degree of engagement was usually consultation with few cases of partnerships. Students were generally in passive roles, while the administration and lecturers initiated and conducted projects, practices, and studies.

This situation did not accommodate the current context in which the co-creation of knowledge, design thinking, and user experiences were highly valued. The CDIO framework prided itself on the creation of innovation and application in learning in the real contexts and stakeholders. It would be logical to formally and extensively include the stakeholders that were personally and most affected by the education, namely, the students.

Considering by the spheres of engagement against the CDIO Standards and proposed optional standards (Malmqvist et al., 2017, Malmqvist et al., 2019), (1) the management, which included the policy, mission, vision, and the administration, supported the Standards 2, 6, 9 and 10. The inclusion of students into committees affected the way that learning outcomes, resource management, and the method of performance evaluation of staffs. Most dominantly, the sphere (2) the provision of the education program, including the curriculum revision, teaching, and assessment, involved Standards 3, 5, 7, 8, 11 and 12 that concentrated on the curriculum development, the methods of teaching and learning as well as the assessment and evaluation. The sphere (3) profession with industry, research, and entrepreneurship supported the Standards 4 and many optional standards on research-integrated education, and entrepreneurship. Lastly, the sphere (4) the service to society and community sphere supported the Standards 5 and 7 as well as optional standards on industrial engagement, sustainable development and workplace and community integration.

The extended CDIO framework and syllabus demanded that "students and faculty have greater awareness and access to tools to promote (i) student engagement in their own graduate capability development …" (Campbell et al., 2009). This optional standard would support this framework by clarifying the definition, achievement, process, and evaluation.

Due to different institutional culture, there would be several approaches to implement this optional standard as different best practices could be used (Hunt et al., 2018). By comparing these practices, one of the most directed methods was to create an administrative platform for involvement of student representatives and then integrate that platform into the program administration and decision making processes. Hence, students would have a formal channel of authority and involvement via their representatives. The involvement of students in the implementation of CDIO standards could be formally channeled via this student platform. With a small group of students in different year of studies, long-term goals on the spheres of involvement could be formulated and activities could be coordinated and improved over time. Also, the resistance from lecturers would be lessen as the program committee would act as the interface.

By being accepted as an optional standard, the student engagement platform would be highlighted; the practices could be more active, systematic, and holistic. Students would be better motivated as the student engagement platform neatly supported all the three basic needs for intrinsic motivation - the autonomy, relatedness, and competence (Leong et al., 2016). Educators and administrators would have a system that facilitated the operation, feedback, and development in the spheres of administration, academic, profession- and community-related aspects. More practices with student engagement as the main component would be studied and reported more systematically. Hence, it would be easier for best practices and lessons to be compiled, reviewed, and promoted for the CDIO and broader teaching and learning communities.

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CDIO Implementation

ASSESSMENT FOR ACADEMIC LEARNING DURING THE COVID-19 PANDEMIC

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ABSTRACT

The COVID-19 pandemic has caused the closure of university campuses around the world including RMUTT, Thailand. The on-site classroom sessions are replaced by full online learnings. One of the most challenging issues the teaching staff encountered is how to deal with the usual midterm and final examinations which normally take place on campus. This paper presents the results of the experiment focusing on an Assessment for Academic Learning with assessment activities which are designed and practiced with the aim to promote the students' learning. The experimental subjects are a Hydrology Engineering course at the agricultural engineering department and a Production Planning and Control course at the industrial engineering department. The objectives of the experiment are to implement self-, peer- and rubric assessment tools, observe perception changes on ourselves and our students, and provide feedback to assist students in improving their learnings. The methodology includes the implementation of a constructive alignment and a four-step teaching-learning-assessment process. An online survey was conducted to collect students' comments on the online teaching-learning-assessment activities. The results show positive changes in our students, fully engaging with the given task. The assessment tools involved more active participation from the students. The self-, peer-, and rubric assessment helps the student review their learnings, ask for clarification, prepare themselves for next classes, and improve quality of their individual and group assignments. The crucial points for successful online learning and assessment reflected from the students are self-management and time management, as well as a quick feedback from the teachers.

KEYWORDS

Assessment for learning, peer feedback, self-assessment, Standards: 8, 11

INTRODUCTION

Assessment methods and requirements probably have greater influence on how and what students learn than any other single factor, (Boud, 1988). In the context of CDIO framework, Crawley et al. (2014) states the importance of learning assessments to support student and program success. This includes assessing the students' achievements from multiple and diverse sources, integrating teaching and assessment, so that the improvement of assessment also improves teaching. Berglund and Karltun (2016) shared their experiences in using several assessment methods to fulfil learning outcomes and encourage deep learning. This included objective tests, essays, case studies, problem-based assignments, professional practice, seminars, oral presentations, oral examination, reflection tasks and open-book examination.

Leong et al. (2016) publicized a systematic approach in enhancing students' self-directed learning and motivation at Singapore Polytechnic. At the same time, the institute provided faculty development programs to enhance teaching skills. One module is an Assessment for and of learning, in which the teacher should be able to design and implement formative and diagnostic assessments, design and implement summative assessment to record the students' achievement (Leong et al., 2016). Harlen (2005) suggested that the teacher should explain the purpose of summative and formative assessments to be used in the course, use formative assessment to express a sense of student's learning progress, provide feedback to help the students develop their learning further and support the development of students' self-assessment skills.

The COVID-19 pandemic has caused the closure of university campuses around the world including RMUTT, Thailand. The on-site classroom sessions are replaced by a full online learning. A number of literatures recommend ways to teach online and give feedback (Puffelen et al, 2018, Meikleham and Hugo, 2017, Lauritsen, 2017). When the teaching and learning activities take place, it is important that students receive guidance on how to study and work to meet the learning goals (Puffelen et al., 2018). Moreover, Meikleham and Hugo (2017) suggested that instructors who are considering implementing online components in their course delivery should consider creative ways to open informal channels of feedback.

How to enhance our students' learning with formative assessment and valuable feedback becomes a point of discussion in today's education. Black et al. (2004) has stated that formative assessment is an activity that provides information that teachers and learners can use as feedback in assessing themselves. Moreover, good feedback involves the teacher to facilitate the development of self-assessment, encourage dialogue around learning, clarify performance criteria and goals, provide opportunities to close the performance gap, deliver high quality of learning information, and encourage positive motivation, (Nicol and Macfarlane, 2006). Lauritsen (2017) researched on how the student experienced the quality of feedback on a digital platform with rubric criteria. The findings revealed that rubric criteria and feedback were helpful to the student. The students required more explanation of their mistakes as well as how to improve their work in the best way.

This paper presents a result of the experiment focusing on an Assessment for Academic Learning (AfAL) which the assessment activities are designed and practiced with the aims to promote the students' learning. CDIO Standard 11 states that assessment methods should address both disciplinary knowledge as well as personal, interpersonal, and system building skills. A variety of methods also allows for different learning styles and results in increased reliability and validity regarding the assessment process. Teaching and learning activities in 2 engineering courses are based on Active Learning concept (CDIO Standard 8)

The experiment objectives are:

1) Implement self- and peer-assessment tools as a part of formative assessment

2) Observe the change in the perception of assessment from ourselves (as teachers) and from our students.
3) Use the information to learn more about our students' learning and to improve our teachings.
4) Provide feedback to the student to help them improve their learnings.

METHODOLOGY

The authors have implemented the theory of Constructive Alignment (Biggs & Tang, 2011) since the adoption of CDIO at RMUTT in 2014. It becomes our routine when planning the course. Moreover, in order to close the loop to improve student learning, the authors implemented Suskie (2018)'s four-step teaching-learning-assessment process. Each step was explained below:

1) Establishing clear, measurable expected *outcomes* of student learning. Revised Bloom's Taxonomy (RBT) is used to define intended learning outcomes (ILOs) of the course and each chapter.
2) Ensuring that students have sufficient *opportunities* to achieve those outcomes with several active learning methods.
3) Systematically gathering, analyzing, and interpreting *evidence* to determine how well student learning matches our expectations.
4) Using the resulting information to understand and *improve* student learning.

Table 1 shows details on 2 engineering courses in the experiment.

Table 1. Details of Two Courses in the Experiment

Course Name	Production Planning & Control (PPC)	Hydrology Engineering (HE)
Department	Industrial Engineering	Agricultural Engineering
Student	Year 3	Year 3
Type of course	Mandatory 3 credits	Mandatory 3 credits
Length	15 weeks	15 weeks
Class size	Big (100-200 students)	Small (20-30 students)
ILOs	1) Forecast the future demand by using quantitative analysis 2) Aggregate plan and issue a master production schedule 3) Manage inventory by using deterministic and stochastic models 4) Generate a material requirement plan 5) Plan a short term schedule 6) Manage project using CPM and PERT techniques	1) Understand the hydrologic cycle 2) Understand the hydro-meteorology equipment and station 3) Realize the analysis of hydrological data 4) Understand relationship between rainfall and run off 5) Create the unit hydrograph 6) Create the IDF curve 7) Analyse flood frequency

This experiment requires us to meet, discuss and select and plan new formative assessment methods for self- and peer-assessment purposes. The selected assessment tools are listed in Table 2. The result from self- and peer assessment will be used to improve student learning. For teacher's assessment, we have determined a clear rubric in order to give valuable feedback for performance improvement. All observations and data are collected for comparing and discussing the results.

Changes during the Pandemic

Due to the COVID-19 situation in Thailand, the government announced a full online teaching and learning policy. RMUTT provides Microsoft Team and Moodle as default platforms available to instructors and students. However, the instructors can use other online platforms such as Google Classroom and Zoom Meeting. Even though the classes have changed from on-site to online, the teaching concept, learning outcomes and active learning activities remain.

Table 2. Formative Assessment Tools for the Experiment

Formative Assessment Tools	Description	Online Tools
Traffic light	Self-assessment Use green, yellow and red to reflect how well they understand the topic.	Students check their self-assessment on Google form or MS form
3 Stars 2 Questions	Peer-assessment After listening to a group presentation, the listeners give feedback to the presenters Write 3 things their peers did good jobs Write 2 things for things that their peers should have done or should improve in the future	Students post their comments on Moodle or MS Team
Rubric	Teacher's feedback will be given regarding the rubric which is given along with the assignment	Teachers type feedback on Moodle or MS Team

One of the most challenging issues the teaching staff have encountered is how to deal with the usual midterm and final examinations which normally take place on campus. For the PPC course, the instructor replaced on-site examinations with 2 group projects. For group projects, both formative and summative assessment were used to evaluate students' learning and performance. Table 3 displays the grading criteria between on-site and online classes.

Table 3. On-site and Online Scoring Criteria for PPC Course

Assessment	On-site (Regular) Class		Online Class	
Summative Assessment	Midterm examination Final examination	30% 30%	Group project 1 Group project 2	20% 20%
Formative Assessment	Individual assignment Group work	10% 20%	Group project 1 Group project 2 Individual assignment	10% 10% 40%
Class Participation		10%		0%
Total		100%		100%

For the Hydrology Engineering course, the summative assessment (midterm and final examinations) reduced from 60% to 50%. The assignment with formative assessment increased from 10% to 20% as shown in Table 4.

Table 4. On-site and Online Scoring Criteria for HE Course

Assessment	On-site (Regular) Class	Online Class
Summative Assessment - Midterm examination - Final examination	 30% 30%	 25% 25%
Laboratory	25%	25%
Formative Assessment - Report - Presentation	10%	20%
Class Participation	5%	5%
Total	100%	100%

Noted that, this experiment focused on the effect of formative assessments.

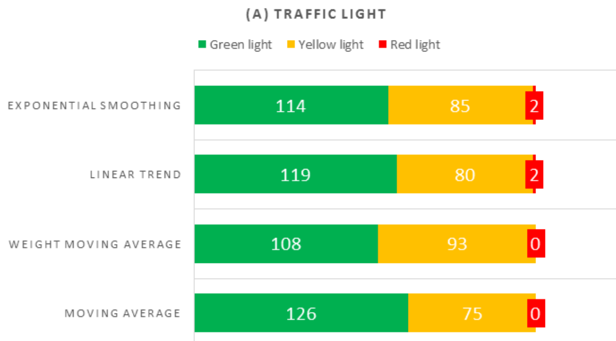
RESULTS OF THE EXPERIMENT

Experiment 1: Traffic Light (Self-Assessment)

Course: Production Planning and Control

Student groups studied the different forecasting methods using a Jigsaw classroom as an active learning technique, followed by working in groups to solve problems. After the class, the students did a simple self-assessment on how well they think they achieved the ILOs by using a traffic light technique. The green light means “I got it!” representing a full understanding of the content and being able to achieve the ILOs. The yellow light means “There are some doubts' ', showing a partial understanding of the content, needing some clarification or reviewing the materials. Lastly, the red light represents “Cannot do it at all”, requiring further support. There was also an open-ended question for the student to type-in which topics that they need clarification or guidance.

Figure 1 shows the result of experiment 1. Figure 1 (A) demonstrates reflections of a total of 201 students, 2 students cannot do the exponential smoothing and 2 students cannot do the linear trend equation methods. The open-ended question “How can I help you?” allows the student to type-in what they are confused about and what they need to help them improve their learning. Figure 1 (B) shows that 6 of them need more explanations, a step-by-step calculation on both forecasting methods. Five students said they would need to go back and review the materials again. Four students were confused which methods to apply, while 2 students needed more examples. One student asked how to answer correctly on a rounded decimal.



(B) "HOW CAN I HELP YOU?"

Open-ended answers	Frequency
I need more explanation on how to calculate step by step for Linear Trend Equation and Exponential Smoothing.	6
I will go back and review the material again.	5
I confused which method to use.	4
I need more examples.	2
How to answer correctly with rounded decimal.	1

Figure 1. Result of Using a Traffic Light Technic

Course: Hydrology Engineering

Week 4 topic was "Rainfall Data Analysis". After finishing the class, the student should be able to create an Intensity Duration Frequency curve and design a reservoir and drainage system. During class time, the students worked in groups to analyze the consistency of rainfall, calculate the rainfall return period, and create the curve. Then the student designed a reservoir and drainage system. A Traffic light technique was used for a self-assessment after the class. All 20 students marked a yellow light which means partly understanding with some doubts. There were no green lights or red lights selected. After getting the result, the instructor asked which part the students needed more clarification, allowing the instructor to review the topic again the following week, giving additional assignments for the student to practice.

Our reflection on the traffic light was that it enabled instant feedback on how well the students see themselves at the end of the class. It was an easy self-check with a quick result. The instructor can provide support right away by answering the questions or reviewing on the specific topic. Moreover, after class support can be video clips that are available online or additional exercise for self-studies.

Experiment 2: 3 Stars 2 Questions (Peer Assessment)

Course: Production Planning and Control

At the end of chapter 1, the students presented their group work to their peers. Each group chose their own business, collected historical sales data, implemented forecasting methods, calculated the forecast errors, and finally suggested which forecasting method was the best suitable for their business.

Course: Hydrology Engineering

Towards the end of the semester on week 10, the topic is "Flood Frequency". The student should be able to analyze the flood frequency and propose solutions for flood protection. Six groups were assigned to study 6 different models, submit reports and prepare oral presentations.

After each presentation, the audience gave a peer feedback using the "3 stars 2 questions" technique. For 3 stars, they wrote 3 things that they think their peers did well. For 2 questions, they gave comments on what to improve in the future. Figure 2 displays an example of a peer feedback using 3 Stars 2 Questions technique.

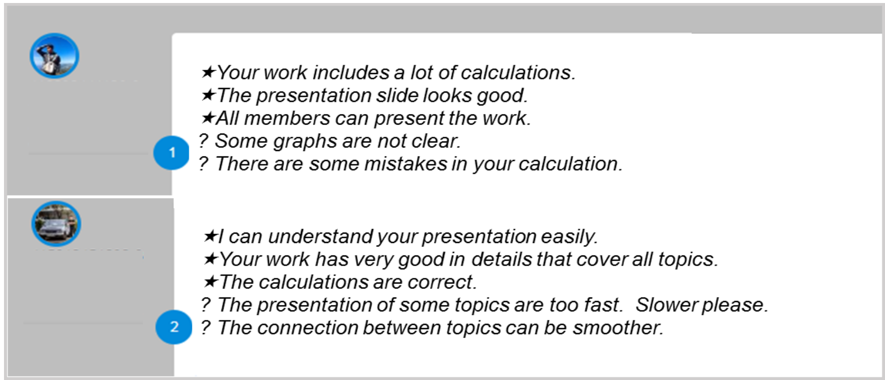


Figure 2. An Example of 3 Stars 2 Questions Peer Feedback

Our reflection on the 3 stars 2 questions method was that it was an easy-to-use peer feedback system for the students. The instruction was given before the presentation started. Since the listeners need to type-in the feedback right after the presentation, they highly focused on their peer's presentation and jotted down interesting points. After reading the feedback, we were impressed with the high quality of feedback that the students can utilize to improve their works later on.

Experiment 3: Rubric (Instructor Assessment)

Course: Production Planning and Control

For group assignment, a rubric criteria was given along with the instruction. So the students knew what the teacher expected from their works. Table 3 demonstrates a rubric criteria for the instructor assessment.

After the student submitted their report and excel spreadsheet files, the instructor gave feedback and comments based on the rubric criteria. After receiving the feedback, the students had 2 weeks to correct and improve their work. The instructor, then, graded the group work based on the same rubric criteria. Figure 3 shows an at least 1-level improvement of the quality of the student's work after receiving the teacher's comment.

Course: Hydrology Engineering

While the students used 3 stars 2 questions to give peer-feedback, the instructor assessed the student work with a 5-scale rubric. The scale was 5-excellent, 4, substantial, 3-adequate, 2-limited and 1-incompetent.

Our reflection on the assessment with rubric criteria was that it was time consuming, but was worth it. The instructor was able to make a clear evaluation of the achievement of ILOs. Additionally, feedback and comments on the good points and areas for improvement played a vital part in supporting the students' learning. As seen in the 2nd submission, it confirmed the effectiveness of rubric and constructive feedback with great improvements on students' works.

Table 3. Rubric for Instructor Assessment

Level	Criteria A: Understanding, Inquiring, Designing	Criteria B: Investigating, Communicating, Evaluating
Excellent	• Use correct formula and perform correct calculation perfectly. • Show a systematic and complete problem solving process. • Make a complete summary with suggestions.	• Use correct engineering language frequently. • Present appropriate mathematical data frequently. • Communicate a complete problem solving process. • Illustrate data with suitable reasons frequently. • Reflect their own work and make suggestion for future improvement.
Substantial	• Use correct formula and perform correct calculation mostly. • Show a systematic and problem solving process. • Make a summary with suggestions.	• Use correct engineering language. • Present appropriate mathematical data. • Communicate a problem solving process. • Illustrate data with suitable reasons. • Reflect their own work substantially.
Adequate	• Use correct formula and perform correct calculation sometimes. • Show a problem solving process. • Make an adequate summary.	• Use appropriate engineering language. • Present data mathematically. • Communicate proper problem solving process. • Illustrate data with adequate reasons. • Reflect their own work.
Limited	• Use formula and perform calculation with difficulties. • Show limited problem solving process. • Make a limited summary.	• Use partly engineering language. • Partly present data mathematically. • Communicate limited problem solving process. • Illustrate data with limited reasons. • Partly reflect their own work.
Incompetent	• Cannot use formula and perform calculation. • Have difficulty in problem solving process. • Cannot make a summary.	• Cannot use partly engineering language. • Cannot present data mathematically. • Cannot communicate a problem solving process. • Illustrate data without reasons. • Cannot reflect their own work.

Group Name	SUBMISSION 1		SUBMISSION 2 (After receiving feedback)	
	Criteria A: Understanding, Inquiring, Designing	Criteria B: Investigating, Communicating, Evaluating	Criteria A: Understanding, Inquiring, Designing	Criteria B: Investigating, Communicating, Evaluating
Top Planning	Limited • Incorrect use of formula • Incorrect in steps of calculations • Not enough evidence for conclusion	Limited • Limited engineering reasoning and investigation • Limited communication and evaluation	Substantial • Correct use of formula and calculation • Correct calculations with systematic problem solving process	Substantial • good engineering reason and investigation • good communication and evaluation
Banana	Limited • Incorrect use of formula • Incorrect in steps of calculations • Not enough evidence for conclusion	Adequate • adequate engineering reasoning and investigation • adequate communication and evaluation	Adequate • Fair use of formula and calculation • Fair calculations with some mistakes	Substantial • good engineering reason and investigation • good communication and evaluation
Mission complete	Adequate • Fair use of formula and calculation • Fair calculations with some mistakes	Substantial • good engineering reason and investigation • good communication and evaluation	Substantial • Correct use of formula and calculation • Correct calculations with systematic problem solving process	Substantial • good engineering reason and investigation • good communication and evaluation
I believe I can fly	Limited • Incorrect use of formula • Incorrect in steps of calculations • Not enough evidence for conclusion	Limited • Limited engineering reasoning and investigation • Limited communication and evaluation	Adequate • Fair use of formula and calculation • Fair calculations with some mistakes	Adequate • adequate engineering reasoning and investigation • adequate communication and evaluation
Horizon	Substantial • Correct use of formula and calculation • Correct calculations with systematic problem solving process	Adequate • adequate engineering reasoning and investigation • adequate communication and evaluation	Excellent • Complete use of formula and calculation • Completely correct calculations with systematic problem solving process • Make a correct conclusion	Substantial • good engineering reason and investigation • good communication and evaluation

Figure 3. Example of Student's Work Improvement after Receiving the Feedback

DISCUSSION

The formative assessment tools that we experimented involved more active participation from the students. We experienced positive changes in our students to fully engage with the given assessment tasks. They used the self- and peer- assessment to help them review their learnings, ask for clarification from peers or teachers, prepare to study for the next session, improve the quality of their individual and group work. Moreover, they had opportunities to develop self-assessment skills.

For ourselves as teachers, we are more attentive and care more to our student's reflections on their learnings. Our perspectives changed gradually along the process. We focused more on how we can support their learnings and achieving the intended outcomes, rather than getting high scores in the examination. We concern more on the on-going process of learning, not only at some point of the semester such as midterm and final summative assessment. When changing from numerical score which represents judgment to text comments, we found that qualitative feedback from the formative assessment was valuable. These experiments allowed us to use the obtained data more effectively to improve our teachings, search for additional resource materials, communicate openly and more often with our students, as well as, help them overcome their struggles.

The effectiveness of the experiment was discussed within 3 criteria as following:

1) Accessibility
   Online platforms and Learning Management System provide user friendly and ready-to-use quiz, template, exit survey, self-assessment, peer-assessment and teacher feedback. It yielded satisfied accessibility to everyone. The data can be preliminary accumulated and analyzed instantly. The peer comment and teacher assessment can be accessed easily.
2) Usability
   Before letting the student perform the assessment, the instructors explained clearly the objectives of each tool, how to do the task, the expectation of receiving critical feedback. We found that the student followed the instruction eagerly and were able to use the assessment tools successfully.
3) Measurability
   Both quantitative and qualitative data in the result section provide evidences the achievement of the experiment's objectives.

CONCLUSION

During this tough time of the pandemic, the authors implemented the Assessment for Academic Learning concept in which the assessment activities are designed and practiced with the aims to promote the students' learning.

To sustain this change, the authors will continue implementing the formative assessment tools in these 2 courses, and to other courses that we will teach in the future. For running the same courses, we may see similarities and differences of the outcomes with different cohorts of students. We plan to try new formative assessment tools and repeat this type of a small experiment together. Future works can expand to comparing the result from changing examination to another type of summative assessment.

In conclusion, the objectives of the experiment were accomplished. It revealed a successful implementation of online tools for self-assessment, peer-assessment, and rubric criteria for teacher assessment. The authors observed changes in the perception of assessment on both teachers and students. The information obtained from the experiment was discussed to understand our student's learnings and improve our teachings. Last but not least, the students used feedback and comments to improve their learnings and increase the quality of their work.

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USING THE SUSTAINABLE DEVELOPMENT GOALS (SDGs) IN AUTOMATIC CONTROL COURSES

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ABSTRACT

An example of how sustainability aspects can be treated in a basic course in automatic control is presented. This is done by connecting the subject to some of the Sustainable Development Goals (SDGs) and giving examples of how automatic control can contribute to the fulfillment of these goals. The examples are inspired and illustrated using videos and images taken from the internet, showing various examples of applications where feedback control plays a crucial role. On several occasions during the course a part of the lecture time is used to show a video, describe how the control subject comes in, and how the use of feedback control via the application can contribute to the fulfillment of the SDG.

KEYWORDS

Sustainability, SDGs, automatic control, Standards: 1, 2

INTRODUCTION

The need for sustainable development is of increasing importance for the world, and it influences all sectors of the society. Also, within engineering education the topic receives increased attention, and one of several aspects is how to incorporate sustainability aspects in engineering education in a suitable way. One approach is to treat the subject in courses entirely dedicated to the field. A second approach is to include sustainability aspects in regular courses when it is suitable, and this is the approach presented here, i.e., to present automatic control as an enabling technology for sustainability. Automatic control is about using feedback for making a system behave in a desired way. It is used in many sectors of society, such as industrial processes, vehicles and vessels, consumer products, and medical equipment. The objectives are often efficient use of energy and other resources together with the desire to minimize the environmental impact, and the drivers often come from economic factors or legislations. The aim of this paper is to show how sustainable aspects have been incorporated in a basic course in automatic control using the UN Sustainable development goals (SGDs). This is done by presenting examples of practical applications of the subject and to show and discuss how the examples relate to one (or several) of the SDGs, and how feedback control can contribute to the fulfillment of the goal.

Within the CDIO Initiative the increased focus on sustainable development can be seen in different ways. For example, in version 2.0 of the CDIO Syllabus sustainability aspects are much more emphasized than in the first version. In e.g., Malmqvist et al. (2019) the need for revision and extension of the CDIO Standards with respect to, among other things, sustainability is discussed. In addition, there are several other examples in the literature where the connections between sustainability, engineering education, and automatic control are discussion. Felgueiras et.al. (2017) discuss the connections in general, but also point out that, see Section 3, "*automatic control is in the basis of sustainability because it allows to optimize the systems consumption*". A comparatively early example where sustainability aspects are included in control education is Baglione and del Cerro (2014) where the focus is on energy efficiency in buildings. A wider perspective is presented in Habib and Chukwuemeka (2019) where the authors discuss the connections between the SDGs and Industry 4.0, where automatic control is an important component, via the areas of cyber-physical systems and automation. Similar perspectives are discussed in Pattison (2017) with emphasis on the ICT (Information and Communication Technology) field.

The paper is organized as follows. Initially, it is discussed how the requirements concerning sustainability are expressed in the overall goals for the engineering education, and that leads to the discussion of how the SDGs can be used to express the society's goals for sustainable development. In the following section the fundamental ideas and concepts within the automatic control subject is introduced, followed by brief outlook over how sustainability and the control subject meet in both academic research and industry. Next the connections between the subject and some of the SDGs are discussed followed by a description how the discussion of these connections are brought into the course. In the following section some additional aspects, valuable in for understanding of some sustainability issues are discussed. Finally, a summary and some conclusions are given.

SUSTAINABILITY IN THE HIGHER EDUCATION ORDINANCE

The requirements for the various degrees within the Swedish system for higher education are specified in the Higher Education Ordinance (2021). For the five-year engineering degree there are twelve goals, and the sustainability aspect is most visible in goal seven, which in translated form says that a graduate should.

show the ability to develop products, processes and systems considering the society's goals for economic, social, and ecological sustainable development.

A similar goal can be found in the requirements for the three-year engineering degree.

To some extent the topic is also visible in goal eleven, which says.

show insight into the possibilities and limitations of technology, its role in the society and man's responsibility for the use of it, including social, economic, and environmental aspects.

These requirements imply that sustainability should be included in the engineering programs. Somewhat simplified, two main approaches can be used. One approach is to concentrate the sustainability issues to one or several courses focusing on the topic, and the other approach is to try to integrate this aspect in all courses where it is found relevant. This paper presents an example of the second approach, i.e., and attempt to include sustainability aspect in a disciplinary course.

When doing this, it is a challenge to interpret the formulation in goal seven about the *society's goals for economic, social, and ecological sustainable development*. On the national Swedish level, the goals for the society are not specified very clearly, and to be able to work systematically with the topic the UN Sustainable development goals (SDGs) can be very useful.

THE UN SUSTAINABILITY GOALS

There are several thorough descriptions of the background to and contents of the SDGs. See for example UN (2021). The graphical illustration of the goals is given in Figure 1.

Figure 1. Graphical illustration of the Global Goals for Sustainable Development.

For each of the goals there are Targets at a more detailed level, but even on this sub-level the Targets are rather wide, and it would hence be naive to think that a single action or subject is enough to tackle the Target under discussion. The approach here is instead to look at examples where applications of the control subject can contribute to some extent.

AUTOMATIC CONTROL

Automatic control is a key enabling technology in many engineering products, processes, and systems. The task for an automatic control mechanism is to make a product, process, or system behave in a desired way. The field is sometimes called The Hidden Technology, Åström (1999) since its presence in the different applications is seldom visible. Instead, the effects can be observed indirectly via the operation of the object under control. Automatic control can be found in many applications, ranging from process industry, aerospace applications, passenger cars and trucks, power systems, consumer products like mobile phones and computers, biomedical engineering equipment, etc. The objectives for using automatic control mechanisms depend on the application, but they involve aspects like quality, productivity, safety, efficient use of energy and other resources, comfort, etc. One of the fascinating features of the subject is that the creation of a real-world control systems includes several disciplines, including mathematical models and tools, process knowledge, hardware and software technology, sensor, and measurement technology, etc.

The starting point when studying an automatic control problem is a problem description of the type depicted in Figure 2, which is an abstraction of the real problem. There are often several steps to take before the problem can be described as in Figure 2, including how to choose the system border, selecting the most important inputs, outputs, and disturbances. Outputs represent properties or behaviors of the system we want to behave in a desired way, e.g., low emissions from a car engine. The inputs represent the ways that the system can be affected, e.g., the air-fuel ratio in a combustion process. Finally, disturbances represent factors that affect the behavior of the system but cannot be chosen, e.g., the ambient air temperature around the combustion process.

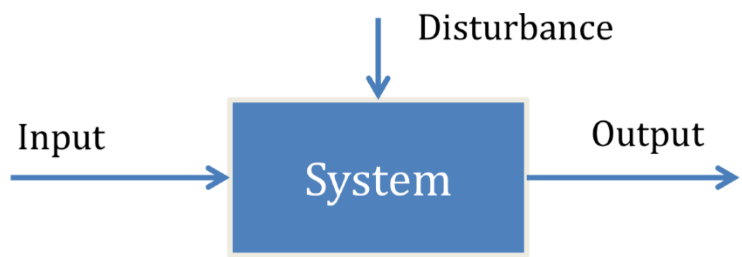

Figure 2. Block diagram description of the system to be controlled.

The key component in automatic control is feedback, which means that the properties of interest are measured and compared with the desired properties, and that the input is selected based on the properties of this difference. In some control problems there are several, and sometimes contradictory, objectives and one must find a trade-off between these objectives.

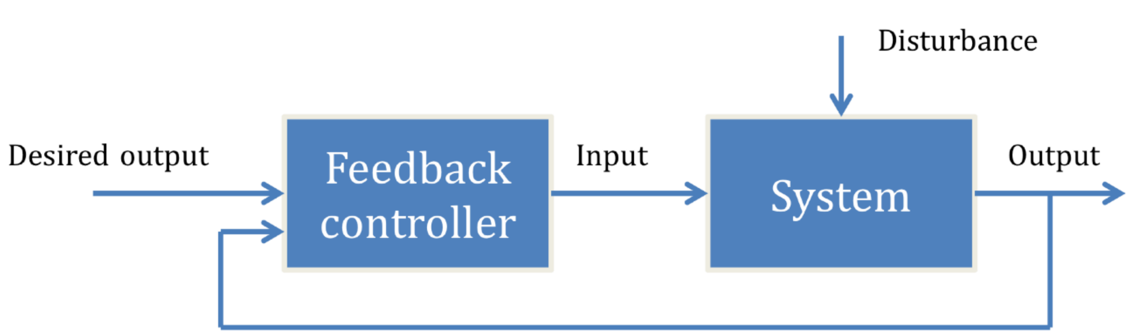

Figure 3. Block diagram description of the feedback control system.

There are many examples of academic research and business activities within the field, aiming at contributing to the fulfillment of the SDGs. One excellent example is Cantoni et al. (2007) dealing with large scale irrigations systems, where it is shown that considerable improvements concerning the usage of water can be obtained using modern methods for modeling and control. Many companies have a clear strategy for how do deal with sustainability aspects, and one illustrative view of how the company's activities connect to the SDGs is found in ABB's Sustainability report, see ABB (2021a).

The automatic control course makes extensive use of "boxes and arrows", as shown in Figures 2 and 3, which is a convenient way to describe systems and their interaction on a more abstract level. The course hence helps the students to develop the systems thinking, which is an important skill, see the CDIO Syllabus, Section 2.3, in both engineering and other fields. The terminology in the figures has an engineering touch, but it can be generalized to by replacing input with *action*, replacing output with *obtained result*, replacing desired output with *desired result* and replacing disturbance with *external factors.* With this more general terminology the representation in Figures 2 and 3 is applicable in many areas outside the engineering field. To determine an action based on the difference between a desired and obtained result is a natural process in numerous fields. The obtained results typically include data of various types, representing the behavior of the object under study, and the whole feedback control mechanism can hence with other words be rephrased as *from data to decisions.*

In addition to the fundamental requirement that the feedback control system in Figure 3 must be *stable* there are three fundamental limitations that always are present and must be considered in the *decision process*, i.e., feedback controller in Figure 3. The limitations are:

- The capacity for actions is always limited, and the actions must be used in an efficient way, given the resources available.
- The obtained result can normally not be "measured" with arbitrary accuracy. The challenges are to be able to measure the relevant things and to measure the relevant things accurately enough. There is always a trade-off between seeing trends and risking being fooled by random variations. A careful analysis and interpretation of the collected data is hence very important.
- The properties of the system, to which the actions are applied, are not exactly known, and the knowledge about the properties of a complex system can sometimes be partly subjective. The more uncertain the knowledge about the system is, the more cautions the decisions and actions must be.

Since decision making takes place in many areas, like e.g., the sustainability field, it is important to have these limitations in mind, and hopefully does the course in automatic control contribute to the understanding of these limitations.

CONNECTING THE AUTOMATIC CONTROL SUBJECT TO THE SDGs

In this paper the connections between the control subject and the SDGs will be illustrated by considering the two goals given below. In the course additional goals, e.g., Goals 11 and 12, are treated in similar ways.

- Goal 3: Good health and well-being.
- Goal 6: Clean water and sanitation

It should be emphasized that these goals cover many disciplines and aspects of society, and that the fulfillment of the goals requires a combined effort from most sectors of the society including the political systems, authorities of various types, etc. The aim of this paper is to illustrate that also a typical engineering subject, such as control, can contribute to some extent. It should be strongly emphasized that the intention is not to convey a naïve impression of the importance of the automatic control subject, but that it can be an enabling factor in many cases.

For Goal 3, i.e., *Good health and well-being*, the following examples are used:

- The use of autonomous aerial vehicles for delivering blood and medicine in areas with poor communication facilities on the ground. There are many efforts and projects in this area, both within research and commercially, and one of the many companies doing this daily is the company Zipline. See Zipline (2021a, 2021b). An autonomous aerial vehicle needs feedback control to maintain the desired height, course, and velocity, plus the related functionality for navigation.

- Humans have a built-in feedback control function that adjust the breathing frequency depending on the need for oxygen (very simplified). When this function does not work, e.g., due to an accident, assistance is needed, and that can be achieved via a so-called ventilator. The task of the ventilator is "simply" to blow air into the patient so that a desired oxygen level is obtained, but this is in reality a difficult task. One reason is that the characteristics, e.g., volume and elasticity, of the lungs are very different between a premature baby, a 25-year-old athlete, and a 90-year-old person. Therefore, the feedback control algorithms must be able to adapt itself to the conditions of the patient under treatment. For this application there are normally no videos available, so the case is described using images. There are many companies delivering ventilators, and one example is Getinge (2021).

For Goal 6, i.e., *Clean water and sanitation*, the following example is used:

- Humans need clean fresh water, and one aspect of this need is efficient wastewater treatment. This is a very tricky control problem, and modeling of that type of systems, which involves the use of subjects like fluid dynamics and chemistry, typically leads to non-linear and multivariable models. Another complicating factor is that it is not always possible to measure all quantities of interest. One example of a commercial actor in the area is the company ABB, and an example of a solution from that company is shown in ABB (2021b).

IMPLEMENTATION

The activities to connect automatic control to the SDGs have been applied during the fall semesters of 2019 and 2020. Both years, one target group was the basic course in automatic control (TSRT22) for the students in the second year of the program in Industrial engineering and management plus students in the third year of the program in Energy, environment, and management. Both are five-year programs, and this is a mandatory course in both programs, which gives that there are approximately 250 students in the course. In 2020 the second target group was corresponding basic course (TSIU61) for the students in the second year of the three-year engineering programs in Mechanical engineering and Electronics, respectively. This course has approximately 90 students.

In 2019 the course was given in the conventional format, which means thirteen lectures, thirteen exercise sessions, and three laboratory sessions using real physical hardware. In each lecture approximately five minutes are used to discuss a practical application of the subject using images or short video clips from the huge amount of such material on the internet. In four of them the application is presented using the SDGs as background, and this is done by first showing the video/images, then discussing how the contents connect to the SDG and how the automatic control subject comes in. This corresponds to the I-step in the sequence Introduce-Teach-Utilize, which is used in the CDIO framework. See pages 96 – 97 in Crawley et al. (2014). It also means that, at this stage, there is no assessment connected to the sustainability questions. The main reason is that a deeper study of some of the application examples would require substantial domain knowledge. Also, since the approach is used in a course with 250 students the volume of the course also has impact on which learning activities that are possible to implement.

In 2020 almost all learning activities were carried out in distance mode due to the pandemic. The only exception was one laboratory exercise that was carried out in the lab using physical hardware. The structure of the lectures was that the presentations of the theoretical contents were pre-recorded and posted on internet, and that the students were expected to watch the films in advance before the scheduled occasions, leading to a flipped classroom format. The scheduled lecture time was used somewhat differently in the two courses. The lectures were carried on using Zoom, and they included quizzes, a Q&A (questions and answers) part, and a longer presentation of examples of real-world applications of automatic control. For several of these application examples there were natural connections to the SDGs, and these were discussed.

EVALUATION

In 2019 the approach was evaluated qualitatively via discussions with the students during the regular course evaluation meeting, and the ideas were received positively by the students. For the program Energy, environment, and management the sustainability topic is close to the scope of the entire education program, and the curriculum contains several courses related to sustainability. The students within the Industrial engineering and management take the course Corporate Sustainability Management parallel to the automatic control course, and the topic and the use of the SDGs is well known from that course. There can hence be some synergy between these courses.

For 2020 the students' view on the connections between the subject and the SDGs was evaluated as part of the regular web-based course evaluation system, and a set of additional questions were added to the regular ones. The new statements read:

A. The automatic control subject has natural connection to several of the SDGs.
B. The connections to the SDGs have increased my motivation for the subject and the course.
C. The connections between the subject and the SDGs have given new insights in possible future jobs.

The students were asked to express their opinion according to the following scale: 5 – totally agree, 4 – partly agree, 3 – neutral, 2 – partly disagree, 1 – totally disagree. There were around 250 students in the course, and the response rate was 32 %. The results are summarized in Figure 4.

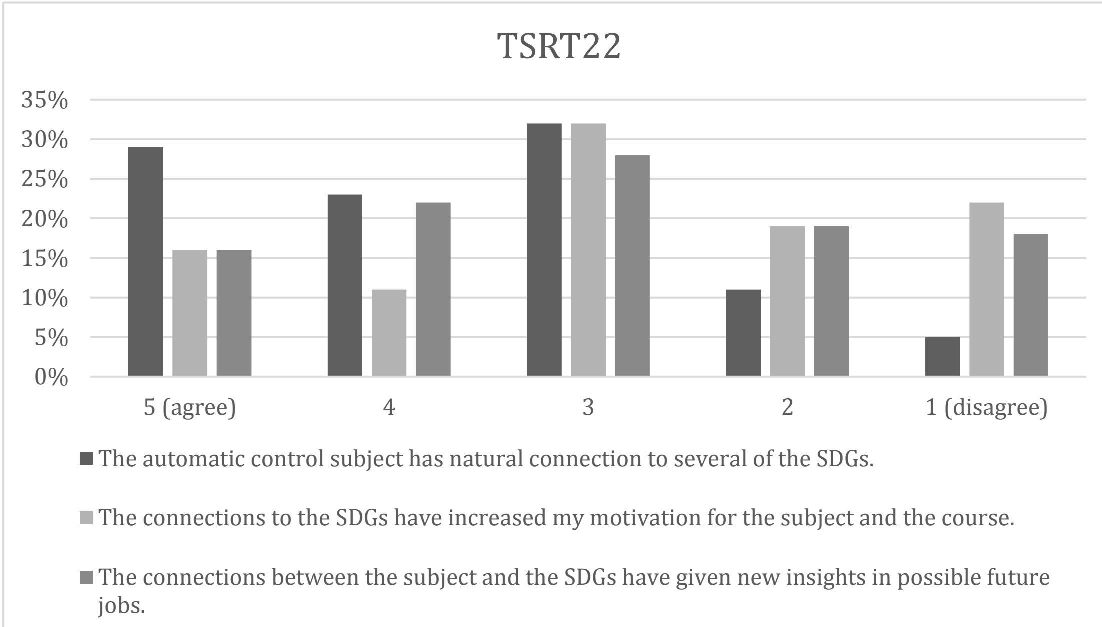

Figure 4. Answers to statements A – C in % for the course TSRT22.

The figures for statement A are overall positive, and a clear majority of the students agrees that the subject has natural connections to some of the SDGs. For statement by the answers are more towards the lower values, i.e., more students disagree than agree. However, since the statement ask about if the connection has *increased* the motivation it does not say anything about the motivation to start with. Other questions in the evaluation indicate that the motivation is rather high to start with, and that the course and the subject is motivated in general. For statement C the opinions are balanced, with a slight shift towards the positive side, i.e., that the students agree with the statement that the connection to the SDGs as given new insight into future jobs.

A difficulty with the interpretation of the evaluation results comes from how the course was organized and executed in distance mode. As mentioned above, the theory parts of the lectures were pre-recorded, and the students were assumed to have watched the corresponding films before each scheduled time for the lectures. The scheduled lecture time was used for quizzes, Q&A, and presentation of application examples, including connections to the SDG. The format led to that seemingly all students watched the films with the presentations of the theoretical contents, but only a subset of the students attended the scheduled Zoom-lectures where the connections to the SDGs were discussed. A consequence of that was that when it was time for the course evaluation the discussion about the connection to the SDGs was new, and it was difficult for them to have any opinion. Keeping this aspect in mind, the interpretation is that the idea has been received positively by the students.

The evaluation for TSIU61, which means the course in the three-year programs, was done using a separate questionnaire, and the results are summarized in Figure 5. The response rate was 28 % for this course.

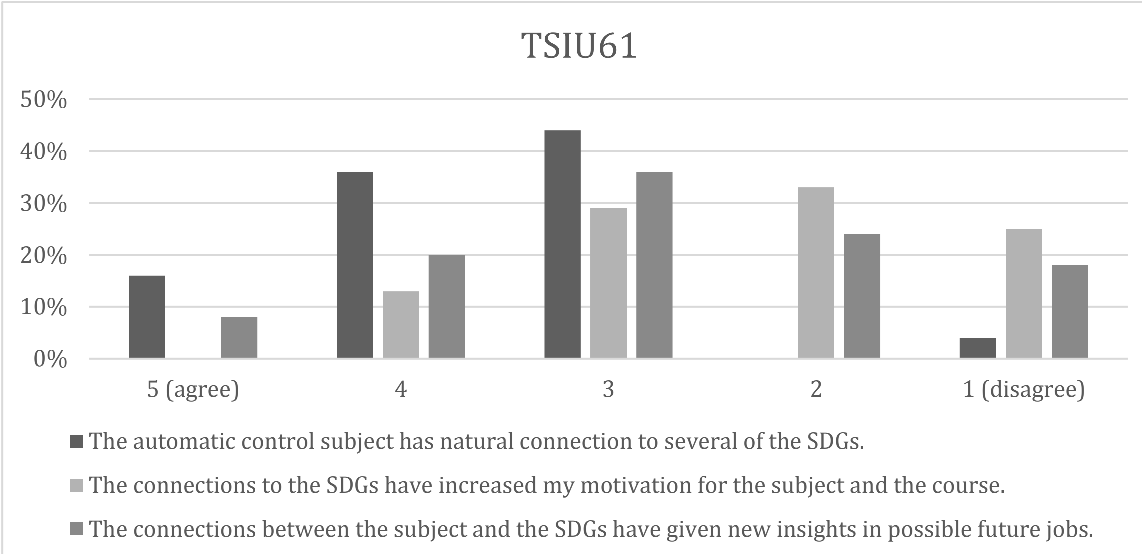

Figure 5. Answers to statements A – C in % for the course TSIU61.

The organization of this course was to a large extent similar to TSRT22 with pre-recorded lectures and the application examples, with the connections to the SDGs, presented at the scheduled Zoom lectures. A common, and positive, observation is that there is a clear and positive opinion among the students that the automatic control subject has a clear connection to the goals for sustainable development. For statement B there is a shift towards the negative side, i.e., no immediate increase of the motivation for the subject, and for statement C the opinions are rather equal. Both these observations agree with what was found for TSRT22.

CONCLUSIONS

An example of how sustainability aspects can be treated in a basic course in automatic control has been presented. The approach is to connect the subject to some of the Sustainable Development Goals (SDGs) and giving examples of how automatic control can contribute to the fulfillment of these goals. The examples are inspired and illustrated using videos taken from the internet, showing various examples of applications where feedback control plays a crucial role. On some occasions during the course parts of the lecture time are used to show a video, describe how the control subject comes in, and how the use of control via the application can contribute to the fulfillment of the SDG. The approach has been evaluated with positive results, even though the distance mode during the fall of 2020 have made both the execution and evaluation of the activity somewhat complicated.

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APPLYING THE CDIO FRAMEWORK WHEN DEVELOPING THE ECIU UNIVERSITY

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ABSTRACT

The use of the CDIO framework in the development of the ECIU University is presented. The paper discusses the relatively moderate adaptations and modifications of the CDIO Syllabus and Standards that are necessary to make the documents applicable also in this context. Since challenge-based learning (CBL) is central learning format in the ECIU University, special attention is given to the connections between CBL method, the conceive-design-implement-operate sequence and project-based learning, which is central in the CDIO framework. The paper presents both general aspects and examples of the applications and activities within ECIU University and Linköping University (LiU). The main messages of the paper are that the development of the ECIU University will benefit from applying the CDIO framework since it offers references for **what** an education should give, in terms of knowledge and skills, and **how** an education program should be designed. In addition, the components of the CDIO framework require a moderate amount of adaptation to be directly applicable. Examples of the ongoing implementation activities at LiU.

KEYWORDS

Challenge-based learning, project-based learning, ECIU University, Standards: 1 - 12

INTRODUCTION

The CDIO framework has existed for around two decades, and it has been used at numerous universities to develop, redesign, and manage engineering education programs. See e.g Crawley et al. (2014) or CDIO Initiative (2021) for thorough descriptions of the framework and presentations of implementation examples. The CDIO framework was designed for engineering education, but there are examples of extensions and applications of the framework to disciplines outside engineering. Fahlgren et al. (2018) was probably the first example of application within the biomedicine field. Another interesting publication is Malmqvist et al. (2016), where various examples, from different disciplines and countries, of applications of CDIO outside engineering are presented. An additional example is given in Martins et al. (2017).

The aim of this paper is to present the potential and the use of the CDIO framework in the development of the ECIU University, which is an initiative involving eleven European universities to build a common framework for a new European University, and the paper is organized as follows. It starts by giving some background information to the ECIU University project and the CDIO framework, and this is followed by a proposal for the use of the CDIO framework in this context. This is followed by a discussion around some of the key aspects, and how they are related to the CDIO framework namely, how to define the desired learning outcomes, the use of the CBL approach, and faculty development, respectively. The paper ends with some concluding remarks.

BACKGROUND INFORMATION

The ECIU University

The European Union (EU) has launched a huge initiative named the European Universities Initiative, where the aim is expressed as follows: *The aim of this initiative is to bring together a new generation of creative Europeans able to cooperate across languages, borders and disciplines to address societal challenges and skills shortages faced in Europe.* See European Universities (2021). This has led to the formation of many alliances around Europe in order to take on this challenge. One of these alliances has been formed within the network ECIU (European Consortium of Innovative Universities), which was formed in 1997 and consists of eleven universities from eleven countries, and where LiU is one of the participating universities. See ECIU (2021). After an extensive application process the proposals from 17 alliances were approved by EU, and one of them is the ECIU University. The project started in November 2019, and it will run for three years. The courses and challenges within the ECIU University have an emphasis on UN Goals for Sustainable Development (SDG) 11 about *Sustainable cities and communities.* In addition to this, the aim of the ECIU University is to create an interdisciplinary educational environment with large flexibility in both room and time.

Organization and Implementation

The implementation of the ECIU University is a complex task with many persons and functions involved. The ECIU University project is led by University of Twente, and the project is organized in nine work packages (WPs). The leadership for each WP is distributed among the participating universities. The management at each participating university depends on the internal organization, and it will not be discussed here.

The organization within LiU includes a working group consisting of the representatives in the different WPs on European level, a steering group with representatives from the highest LiU management level, students, administrative staff, etc. In addition, there are sub-groups for special tasks, and since LiU is responsible for WP5 about Challenge-based innovation there is a sub-group handling various topics related to this WP. Furthermore, there is a sub-group discussing the creation of an Innovation of Education Lab (IEL), which will be connected to the pedagogical unit of the university. The purpose of the IEL is to support teachers developing their competence within CBL.

The CDIO Framework

The fundamental aim of the CDIO framework is to educate students who are "ready to engineer" and to raise the quality of engineering programs, see Crawley et al. (2014) and the web site CDIO Initiative (2021). The framework relies on four key components:

- A "definition" of the role of an engineer.
- Clearly defined and documented goals for the desired knowledge and skills of an engineer listed in the document the CDIO Syllabus (2021), which serves as a specification of learning outcomes.
- Clearly defined and documented goals for the properties of the engineering education program collected in the document CDIO Standards (2021), which works as guidelines of how to design a well-functioning engineering education.
- Methods and tools for systematic development and management of education programs.

According to the CDIO framework, see Crawley et al. (2014) page 50, the goal of engineering education is that every graduating engineer should be able to *Conceive-Design-Implement-Operate complex value-added engineering products, processes, and systems in a modern, team-based environment.* This formulation can serve as a definition providing the basis for the entire CDIO framework. Adopting the definition, it is natural to design and run an engineering education program with this in focus. The CDIO Syllabus is a list of the desired knowledge and skills of a graduated engineer. The document can be found via the CDIO web site, and it consists of the following four main sections:

1. Disciplinary knowledge and reasoning
2. Personal and professional skills and attributes
3. Interpersonal skills: Teamwork and communication
4. Conceiving, designing, implementing, and operating systems in the enterprise, societal, and environmental context – The innovation process

Via the sub-sections and sub-sub-sections, the document offers an extensive list of knowledge and skills, which can be used to specify learning outcomes of individual courses or education programs. The CDIO Standards (2021), which also can be found and explained in detail via the CDIO web site, is a set of twelve components that are necessary for designing and running an engineering program that enables the students to reach the desired knowledge and skills. The CDIO framework offers a variety of tools for development and management of education programs, including for example the so-called Black-box exercise and the CDIO Syllabus survey. These tools are described in some detail in Crawley et al. (2014).

PROSPOSED USE OF THE CDIO FRAMEWORK

Re-phrasing the Starting Point

The starting point in the CDIO framework is the definition of what is expected from a graduating engineer given above and in Crawley et al. (2014). Based on the intentions and scope of the ECIU University a possible corresponding definition could be the as follows. Every graduate from the ECIU University should be able to

Conceive-Design-Implement-Operate complex value-added solutions to societal challenges in a modern, interdisciplinary, team-based environment.

in comparison to the original formulation

Conceive-Design-Implement-Operate complex value-added engineering products, processes, and systems in a modern, team-based environment.

Based on this characterization of the graduates the next steps will be to carry out appropriate modifications and use of the Syllabus and the Standards.

Adapting the CDIO Syllabus

The CDIO Syllabus serves the purpose of being a reference frame in the process of specifying the desired learning outcomes in terms of knowledge and skills of the graduates of a program. The document was originally presented in Crawley (2001), and it has been used extensively since then, including being translated to several languages. Sections 1 – 3 are general and applicable to most types of education situations. The main challenge is to adapt Section 4 to make it suitable, and without going into the exact wordings it is obvious e.g., 4.1 External, societal, and environmental context and 4.2 Enterprise and business context are highly relevant for the ECIU University situation.

Adapting the CDIO Standards

The second fundamental document of the framework is the CDIO Standards specifying *how* an education program should be designed in order to enable for the students to achieve the desired goals in terms of knowledge and skills. Some of the standards are general and work for almost all types of education, while some are specific for engineering education and need adaptation to suit the ECIU University. A proposed adaptation is shown in Table 1.

Table 1. Left column: The CDIO Standards. Right column: Proposed Standard for the ECIU University.

Standard no.	CDIO	ECIU University
1	CDIO as Context	The Context of the education, as defined in the description of the role of the graduate above
2	CDIO Syllabus Outcomes	ECIU University Syllabus Outcomes
3	Integrated Curriculum	Integrated Curriculum
4	Introduction to Engineering	Introduction to CBL
5	Design-Build Experiences	CBL Experiences
6	CDIO Workspaces	Workspaces for CBL
7	Integrated Learning Experiences	Integrated Learning Experiences
8	Active Learning	Active Learning
9	Enhancement of Faculty CDIO Skills	Enhancement of Faculty Skills related to CBL
10	Enhancement of Faculty Teaching Skills	Enhancement of Faculty Teaching Skills as a coach/facilitator/teamcher
11	CDIO Skills Assessment	Assessment related to CBL
12	CDIO Program Evaluation	ECIU University Program Evaluation

Many of the items in the Standards are very general and hence applicable to almost all types of education programs, while some are more directed towards the type of education. The main similarities and differences can be summarized as follows.

Standard 1: Adoption of the vision stated in the definition of the roles of the graduates. Like in the CDIO framework it is crucial to have vision of the role of the graduates as a basis for the design and development of the education.

Standard 2: The expected learning outcomes of the education, specified using the sections of the Syllabus. Starting from the vision of the roles of the graduates a suitable combination of learning objectives from the sections of the Syllabus is formulated. This topic will be elaborated further in the section *Discussion* section below.

Standard 3: To obtain a high-quality education program, it is very important to design a curriculum with courses and learning activities that "fit together". This means that the learning objectives of one course match the prerequisites of courses later in the education. This is a big challenge when aiming for an interdisciplinary education with a high degree of flexibility in time and space.

Standard 4: Introduction to CBL. For students not used to CBL it is important to get an introductory course in CBL before taking on bigger and more complex challenges.

Standard 5: CBL experiences. CBL is a key element in the design of the ECIU University, and it will be discussed in some detail in the section *Discussion* below. An initial study of the connections between challenge-based learning and parts of the CDIO framework was also presented in Malmqvist et al. (2015).

Standards 7 and 8: Integrated and active learning is obvious in an education program with a substantial amount of CBL, such as the ECIU University, since it is a highly student active learning format integrating disciplinary knowledge and skills from all sections of the Syllabus.

Standard 9: CBL is a comparatively new learning method, and for faculty not used to this it will be necessary with appropriate training before starting to use CBL.

Standard 10: In addition to the specific aspects of CBL, a continuous improvement of teaching skills is always desirable. Maybe the largest difference is for the teacher to serve as a coach for the student team. Additional aspects of how to handle the faculty development will be mentioned in the *Discussion* section below.

Standard 11: Assessment of knowledge and skills is always a challenge, and since CBL is a new method for many faculty members involved, special attention has to be spent how to assess the skills developed using this method.

Standard 12: It is always very important to have appropriate methods for evaluating the quality of education programs, and this is even more important when designing a, in many ways new and unique, education such as the ECIU University.

The items of the CDIO Standard cover many aspects of the design of an education program, but the list of items is not exhaustive. There have hence been activities within the CDIO Initiative to extend the list with optional standards. See e.g., Malmqvist et al. (2019), where a list of proposed optional standards is given. Out of the optional standards the *Workplace and community integration* and *Sustainable development* are the most relevant, but for the ECIU University context we would like to propose and use *Stakeholder interaction* as an additional optional standard. This will be discussed in some detail below.

DISCUSSION

As expressed above the most important parts that need to be discussed and developed are the subsections under Syllabus 4, the standards 2, 4, 5, 9, 10, and the proposed optional standard Stakeholder interaction.

Specifying the Learning Outcomes

The Standard 2 is about specifying the expected learning outcomes, in terms of knowledge and skills, of an education to prepare the students for the intended professional role, and within the CDIO framework this is done using the CDIO Syllabus as reference. The Syllabus is a very comprehensive document with a logical structure, and even though it was originally designed for engineering education examples have shown that it is straightforward to modify it to be useful for other types of education programs. However, there are several other examples of documents with similar purpose at the CDIO Standards. A well-known example is the ABET criteria, and the mapping between these and the CDIO Syllabus is described in Crawley (2001). Another very ambitious work is presented in the project Tuning Educational Structures in Europe, see Tuning project (2021). The project has developed an extensive number of results, and among them one can find a list of 31 generic competences, where most of them can be found among the items in the CDIO Syllabus. One additional example is what is denoted as the twelve 21st Century Skills, see e.g., Rotherham and Willingham (2010). The 21st Century Skills include for example critical thinking, communication, and collaboration, which all can be found in the CDIO Syllabus. A final example is the eight Key competences for sustainability, defined in UNESCO (2017). Among them one finds collaboration competence, integrated problem-solving competency, and normative competency. It would be an interesting, but challenging, task to try to find mappings between each of the sets of skills and competences, but this is not the aim here. Instead, the key message is that there are many possible references for structuring the desired learning outcomes of an education, and that it, from the perspective of the ECIU University, is important to use a common such reference. An additional message is that a suitably adapted version of the CDIO Syllabus would serve this purpose.

CBL Experiences

The Standard 4 and 5 are about the use of CBL as learning format. CBL has received considerable attention during the last two decades and there are numerous publications and web sites presenting the fundamental ideas and implementations. See for example Challenge Based Learning (2021) and Membrillo-Hernández et al. (2018). It is not the aim of this paper to give any overview of the topic, and instead we refer to publications in the field. As pointed out by several authors there are both similarities and differences between CBL and problem-based and project-based learning, and there are several suggestions for how to characterize these differences and similarities. However, from the perspective of the ECIU University it is important to, as far as possible, describe the net values, in terms of learning outcomes, that are obtained by using CBL in comparison to problem-based and project-based learning. The additional values of using CBL are often described in general and vague terms, but to give a correct picture of the approach and motivate the use of CBL it is important to express this more clearly. In that process it would be useful to have a common reference when discussion and specifying learning outcomes, as discussed in the sub-section above. An interesting exercise would be to go through the CDIO Syllabus and point out the learning outcomes for which CBL is a more suitable format than other approaches. Such an exercise could also reveal if some learning outcomes should be added to the document.

As mentioned, there are many aspects that are similar, or related, when comparing CBL with the other approaches, and when applying CBL within the ECIU University is that it is important to make use of the big source of experience that is available within the CDIO Initiative and elsewhere. Some of the most important aspects are the following.

Work Process

One proposed work process for CBL consist of three main stages, where each stage consists of three sub-stages:

- Engage – big idea, essential questions, challenge
- Investigate – guiding questions, guiding activities/resources, analysis
- Act – solution, implementation, evaluation

Comparing these stages with the CDIO sequence, i.e. the steps conceive, design, implement, and operate, it is obvious that, even though the wordings are different, there are strong similarities. It starts with a challenge, an idea or an identified need, and results in an implemented solution. The actual implementation and execution of the learning activity can be different, and it involves aspects such as the planning and use of time and other resources, regular meetings with the persons having different roles around the team, and components of assessment.

Teamwork

In CBL, as well as in project-based learning, one of the learning outcomes is to develop the teamwork skills of the students. This is stressed in sub-section 3.1 of the Syllabus, where various aspects of teamwork are listed, such as team formation and roles in the team. In CBL the high degree of inter-disciplinarity will add an extra dimension to the formation and operation of the teams. Within LiU, group contracts have been used for several years in both project-based and problem-based learning activities to support the teamwork. In addition, various tools, and documents for reflection over the lessons learned are used in many of these learning activities. The experiences concerning various aspects of teamwork that have been collected within the CDIO network have the potential to be very useful in the development of the ECIU University.

Roles around the Team

There are several persons with different roles around the team, and the names and tasks of these roles are not unique and can have slightly different meaning in different contexts. The *challenge provider* represents the stakeholder proposing the challenge. Even though there are differences there are some similarities with the role of the sponsor/customer role, which is used in some project-based courses. See for example Svensson and Gunnarsson (2012). A key aspect is the role of the teachers, and in CBL it is clearly stated that the role of the teacher should be more of a coaching role. Several names have been proposed for this role, including *coach* and *facilitator.* Within the ECIU University word *teamcher* has been proposed to stress the close interaction between the teacher and the team. There are also connections to the word *supervisor,* used in project-based and problem-based learning. However, it should be stressed that it is how the person acts in the interaction with the students that is important, and not the name of the role, but to reduce the risk of confusion it is of value to have a common vocabulary.

Choice and Formulation of Challenge/task

In CBL initial effort is invested on the Engage-phase which involves the identification and forming of challenges that are appropriate for a specific course, and some important characteristics are summarized here. A qualified challenge must be able to engage students and be relevant. In the ECIU University the framework of SDG 11 will be a guiding criterion for relevance. The challenge also needs to be complex, contain multiple areas of knowledge base (interdisciplinary), be scalable, have innovation potential and offer possibility for the students to find multiple solutions. The challenge provider is central in the identification and forming of the challenge, but since the aim is also to motivate the students, there is a need for discussions between the challenge provider and the student group. A final fine-tuned challenge is then formulated to represent the starting point for the learning in the course. In comparison with CDIO, due to the Engage-phase in CBL the process starts earlier than the CDIO-process.

Communication

Whenever the expected learning outcomes from an education is specified, see e.g., Section 3 of the CDIO Syllabus, the issue of communications comes up, and so also within CBL. This includes written and oral communication in various forms, as well as the use of electronic tools for communication, and also here the CDIO network offers extensive experience.

Faculty Development

As pointed out in Standards 9 and 10 the competence development of the teachers is a key component in all types of education, and so also when it comes to CBL. Several activities related to faculty development around CBL have been carried out or are in the implementation phase. ECIU University is of course one driver behind the need for faculty development concerning CBL, but the interest in CBL at LIU is increasing in general. During the fall semester of 2020 the CBL-based course Sustainable development (3 ECTS) was given for the first time. As a preparation a series of workshops were arranged for the teachers in the course, and the workshops were carried out using a CBL format. The pedagogical unit of the university is preparing a CBL course open for all teachers at LiU, and it will be given during the first half of 2021. The course will make use of experiences gained during the development and execution of the Sustainable development course. The pedagogical development group at the Faculty of Science and Engineering at LiU is funding a development project aiming at developing the use of CBL within the engineering education programs at LiU. The team in charge of the project is based at the unit for Innovation and Entrepreneurship, but the aim of the project is to also reach teachers and courses in other disciplines.

Malmqvist et al. (2015) point out that there are tight links between CBL and both problem-based learning and project-based learning, and it is claimed that CBL can be seen as a step forward from these approaches. Since LiU has a long and solid background in both problem-based and project-based learning, there is a strong foundation for faculty development in CBL. LiU was a pioneer concerning the use of problem-based learning within the education programs at the Faculty of Medicine and Health Sciences, and via, primarily, the participation in the CDIO Initiative, there is a solid experience in project-based learning.

Another big source of experience is the findings from the so called “InGenious course”, with the official name InGenious - Cross Disciplinary Project (8 ECTS). The course has its background in what was called Demola, and it has been running for approximately ten years.

Even though not explicitly stated so it has most of the key features of CBL course. The InGenious organization is tightly connected to the ECIU University, and more information can be found via InGenious (2021).

Stakeholder Interaction

We here propose the optional standard Stakeholder interaction. Interaction with the surrounding society is an important factor for all types of education to ensure the relevance of the education. For the ECIU University and the strong emphasis on CBL the stakeholder interaction is even more important. A key idea of the ECIU University is to bring in challenges from various types of external stakeholders, including both companies and public organizations. A first step in this direction was taken in February 2020 when a so-called Society Quest was arranged at LiU. The participants at the event came from the participating universities in the ECIU network, but also stakeholders from the public sector, e.g., regions or municipalities, connected to the partner universities. The event led to the formation of a database over challenges to be dealt with in the CBL-activities at the different universities. A pilot project to find suitable formats for interaction with industry stakeholder is carried out in collaboration with Toyota Material Handling, that has a site with both R&D and production in the geographical neighborhood of LiU. The pilot is however more focused on research collaboration.

CONCLUSIONS

The use of the CDIO framework in the development of the ECIU University has been discussed. The paper has presented the adaptations and modifications of the CDIO Syllabus and Standards that will be necessary. The connections between CBL and the conceive-design-implement-operate sequence and project-based learning have been discussed. The main conclusions are that, even though some modifications will be needed, the CDIO framework is a very useful in the development of the ECIU University. The paper has also presented various aspect of the implementation of the ECIU University at LiU.

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EFFECTS OF MIGRATING LARGE-SCALED PROJECT GROUPS TO ONLINE DEVELOPMENT TEAMS

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ABSTRACT

This contribution presents challenges in a project-based course with large project groups that have arisen through the COVID-19 pandemic. Traditionally, the course has been dependent on a larger number of physical meetings to coordinate the work, and to solve the task technically. However, the pandemic requires that work must be redirected to forms where students work online, physically distributed as much as possible. It is furthermore interesting to see the course in the core context of its main theme, that is, software engineering. Here, the pandemic actually has consequences on software engineering subjects, such as, choice of development methods. The course teachers (authors of this contribution) have especially observed this adjustment, and documentation is kept on how the students meet these new challenges through online discussions, and questionnaires.

KEYWORDS

Project-based education, Teaching on distance, Software development styles, the COVID-19, Standards: 5, 6, 7, 8

INTRODUCTION

Software Engineering 2 (SE2), is a 15-credits course, which runs part-time during the first semester of the third year for students in the international Software Development Program, Kristianstad University, Sweden. The course has a focus on one main project, where students shall develop Smart Home-techniques in project groups of approx. 15 participants. A project group is then divided up into subgroups of about 3 to 4 students to solve subtasks of the main project. At the autumn 2020 semester, the course involves about 45 students, which means that there are three major groups, each with the same main project purpose.

Due to the COVID-19 pandemic, that strongly has affected the teachings during the autumn 2020, the ways to provide SE2 have been drastically changed. SE2 is normally a campus-based course, that is heavily dependent on physical meetings for reasons, such as those of effective communication, and integration of technical solutions. Instead, physical meetings have been more or less fully replaced by online-activities. Due to this upcoming situation, the teachers have seen that several conditions that previously were considered given, have been needed to be considered with new approaches. Example in this include:

- Within a project group, the development process must be coordinated in a uniform manner, where requirements are put on project-documentation, and integration of the subgroups' technical solutions. This means that the course has great demands on teamwork, and communication at several levels, such as within the subgroups, within the project group, and towards the teachers, all preferably done localized, typically campus-based.

- Besides from the project, SE2 also covers principles, and theoretical foundations for large-scale software development. Distributing the development geographically puts such principles in focus. For example, agile development processes correspond to development groups with physical meetings for quick decisions. The students have been trained from previous courses in agile development processes, and questions arise according how these can be applied to cases of distributed development.

At the online-meetings between the teachers and students, during the autumn 2020-course, several aspects have been discussed, such as the state of health, how the work is progressing, what plans there are for integrating the subgroups' technical solutions, etc. Several reflections have been expressed such as: "*Difficulties in communicating in larger teams, online meetings are often controlled and do not allow for spontaneous comments*"; "*More like presentations, than discussions*"; "*Coding previously done together, is done by sharing screen*"; "*You get more and more used working like this*". Moreover, several discussions have led to interesting open questions, unfortunately lying outside the scope of this contribution to be answered.

In conclusion, it can further be mentioned that the new situation that has arisen can contribute to several pedagogical benefits that also correspond well with several CDIO-based learning objectives (CDIO, 2021). While hard and difficult, this new situation can therefore also be valuable, both for the teachers' internal reflections on teaching, and for the students' awareness of a possible future professional practice in change.

BACKGROUND

A brief course overview

The core structure of the course has been the same during several years, even though changes have been done to improve the course (Einarson & Saplacan, 2017). A main purpose in developing Smart Home-techniques have been to support disabled people for the sake of their independence (Einarson & Teljega, 2020). The technical challenges require several technical perspectives, concerning user-controlled units, home devices, and a mediating server, all that need to be developed and integrated to work as a whole (Figure 1).

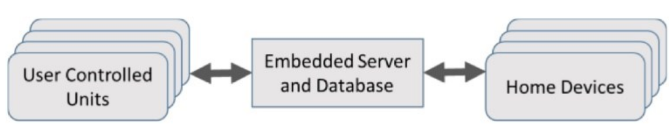

Figure 1. A Smart Home-System overview (Einarson & Teljega, 2020).

This in turn requires a project group being divided into (at least) four subgroups (Figure 2), where they take care of one of the following main subjects: 1) Technical devices such as lamps, fans, and temperature to be controlled and monitored, from 2) Smart Phones and 3) Web-based interfaces, and 4) the Server that mediates between the different system parts. Besides from this, among the students there is a dedicated Project Manager, and Requirements Manager.

The students are trained in an agile process style (Alliance, 2020) from previous courses. Still, the SE2 project process, mainly corresponds to a more controlled way of working, through the Unified Process for Education (UPEDU, 2014), which is based on an iterative and incremental process model with four main phases, i.e., *Inception*, *Elaboration*, *Construction*, and *Transition*. In Einarson (2011), it was shown how well those phases correspond to the CDIO's *Conceive*, *Design*, *Implement*, *Operate*, and that using the Unified Process as a model for the project process clearly puts the course in a context of CDIO-based education.

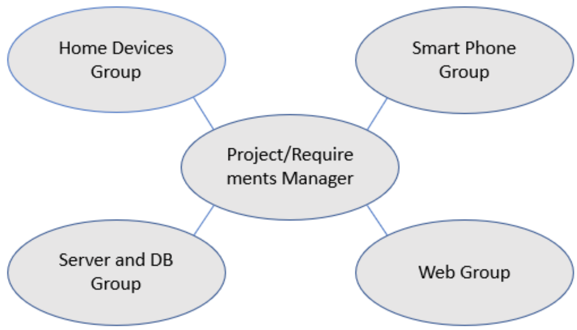

Figure 2. Project organization.

In SE2, the iterative and incremental way of working, is corresponding to project meetings (PM) between teachers and students, and where increments relate to progress with respect to phases of the project. At the PMs, artefacts, delivered by students are communicated, where those artefacts correspond to documents representing project *Requirements*, *Design*, *Risks*, and more. Figure 3, outlines the process, with project meetings, student presentations, and relation to phases.

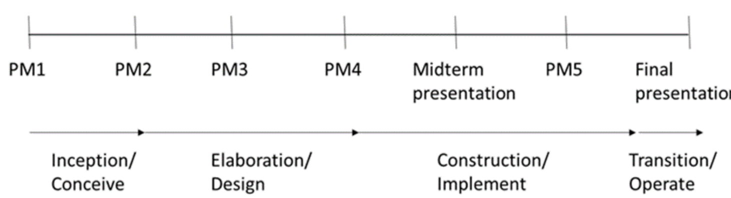

Figure 3. Process organization, where time-line corresponds to autumn semester, 2020.

Communication, especially pointed out through CDIO Syllabus, Section 3, on *Interpersonal Skills*, is here strongly significant for the progress of the process, and for efficiency reasons, preferably done through physical meetings. Communication can be seen at different levels, such as between:

- teachers, to coordinate course
- teachers and student groups, especially at the PMs
- students in subgroups, and project group as a whole
- students in subgroups

Besides form this, students shall develop, test, and integrate their technical solutions. Within this context, the migration to online-based education is especially critical.

On process models

Process models may be put on a scale based on grade of agile methods for development. At one point of that scale there are the authoritative, planned, and controlled methods, and at the other end of the scale there are the agile styles, with more liberal perspectives on decisions, planning games, and brainstorming at common physical places. Figure 4, proposes which is the most appropriate choice, based on known circumstances.

- Non-agile methods to be chosen when:
  - Goal is clear
  - Many requirements, which are clear
  - Project has many external dependencies
  - Fixed contract
  - Fixed deadline
  - Geographical distribution within the project group
  - Changing costs are too high
- Agile methods to be chosen when:
  - Fast useful result is desired
  - Requirements are vague
  - Changing situations
  - Project is implemented in the same place

Figure 4. Choice of project method (Sommerville, 2015).

For the project in SE2, that project is normally run through a rather agile style, which corresponds well to the parameters of Figure 4’s right side, even though the process, at an umbrella level, is run in a controlled way according the UPEDU-process model. Still, especially, within subgroups, the working method is highly agile. However, the current situation with online-development, certainly has effect on localization of development, which is forced to be distributed. This in turn, has effect on communication, and how an agile process is driven forward.

REFLECTIONS DURING COURSE

Communication between teachers and students has mainly been conducted through PMs and occasions for student presentations, which also is the usual way to provide the course. However, it can be seen that communication between these meetings, primarily via email, has been more frequent this time. At PMs, the teachers have initiated discussions that also have concerned the special situation of the pandemic, and documented this, with the students' consent. An observation was that both students and teachers adapted to the situation over time. At early PMs students could argue that “*Working in a team is always a challenge and it is especially tricky in our case since we are working as a remote - distributed team*”, while at later PMs express that: “*More used to the online-thing*”, or “*It gets better for each week*”.

Below is a subset of points of discussions and observations, with the addition of the teachers' own reflections. While discussions during the PMs have been free, subjects of those have afterwards been categorized as follows:

- Process model – Controlled vs. Agile
- Health and Social Concerns
- Communication and Conflicts
- Changing Work Situation

Process model – Controlled vs. Agile

We here again refer to the discrepancy between planned (or control)-based process-styles and agile process-styles (Figure 4). As previously mentioned, the students are trained in agile software development since before. It is usually also this method that has been used at the course SE2, although the process is guided by clear phases with milestones and formal meetings. The agile method includes several sub-methods, such as, common brainstorming, and pair-programming (one is programming, the other guides and checks for correctness) (Alliance, 2020). Such sub-methods are normally dependent on physical meetings, and will suffer from the forced distributed, online-based development.

As claimed by students: "*Meeting physically works better, more efficient",* or "*War-rooms* (physical places for brainstorming ideas) *are beneficial, with white-board for ideas*".

Here it can be seen that communication needs to be handled in new ways, as stated by a student: "*Preparing ideas before meetings. That is, ideas are carefully prepared and presented, rather than elaborated on at the online-meeting*". When it comes to joint-development, this was solved by sharing the screen, and thus pair-programming as a method could actually be used.

How to implement the chosen process style was actually left to the project groups. This means that the dedicated project group leaders (Project- and Requirements Managers) had a responsibility where a leadership style of choice could be significant. Leadership style was also a point of discussions at the PMs, and questions were raised, such as: *Does a too liberal-democratic management style actually work in this situation*? *Where on a scale from too authoritative, to too liberal democratic management, would leadership be preferable*?

The teachers could see a difference in leadership style between the groups, where the first of the groups' leaders were clearly authoritative (even though collaborative), the third was at the other end-point, and the second somewhere in between. The outcome was in clear favor of the first group, that worked consciously authoritative from the beginning. As expressed in one of the documents: "*Effective communication and collaboration within a development team is fundamental for the success of the project, more importantly so during the COVID-19. Since the beginning of the project, we strive to create and refined a collaborative project management method to coordinate the team's operation*". It is certainly hard to tell if the higher grade of success is due to an authoritative leadership, or if there are other reasons. Still, in addition to this, the third group had the most problems, with quite serious conflicts (more on that below).

An interesting question arises from teachers: *Can Software Development be agile even though development is distributed, and communication is clearly controlled? In that case, or if not: to what degree can this still be realized?*

Health and Social concerns

According the pandemic, the teachers (and students) are subject to the rules and policies that are expressed in the context of the pandemic, and where you beforehand do not know how they will be like. From the point of view of the student project, they have to prepare for a *Plan B*, where equipment of the lab needs to be replaced by alternatives. From the point of view of the process, students are encouraged to treat the situation from a Risk Management perspective. Some, but not all, students followed that recommendation, as exemplified by:

Risk 4*. Illness and inability to meet at the lab can result in some issues –* **Impacts***: Illnesses not allowing members to meet*, **Indications**: *A group member could fall ill at any given time, and during times of the pandemic can harm other members in our group*. **Mitigation Strategy**: *Follow pandemic procedure and attempt to prevent exposure to high risk locations of people*.

Risk 9. *Falling ill has always been a concern no matter the circumstances, but in the midst of a pandemic, it has become an even bigger and prioritized concern. We see the impacts of the pandemic, influencing the course structure and communication. Everything is digitalized, meetings are now taking place online instead of having physical meetings, face to face. The subgroups that were supposed to work together in person are now only communicating via Discord or Zoom. It is important to include sickness or falling ill because the possibility of it occurring is very likely. If one or more group member(s) were to fall ill, the project would be affected in certain ways such as not being able to deliver the work on time and delaying internal deadlines, etc.*

Each PM started with a discussion regarding the health status of the students. It turned out that no-one actually got sick from COVID-19. Still, also social concerns were discussed. Some students claimed that "*Working from home is a dream come true*", while others expressed that "*You lose focus when you are working from home*", or "*Mixed, blended, is best*". A conclusion from teachers is that working distributed did not seem to be very socially dramatic. Some claimed that they never felt free though, like they always were available and online. Still, teachers addressed the importance in working in sustainable pace, and accepting asynchronous communication, which means that it may take time before a request got a response, depending on habits.

Communication and Conflicts

At the PMs each student shall answer to his/her contribution to the work. Online-meetings are most often characterized by controlled manners. Communication is restricted to one specific theme, with one speaker at a time, and no room for spontaneous comments. This also means that teachers find themselves in a situation where it is hard to give feedback on detailed levels. With about 80 documents to read before each PM, the demand on controlled communication implies that mainly the bigger concerns are treated. There were also complaints from some students according lack of appropriate feedback at the PMs. Moreover:

- *On the positive side*, it can be mentioned that the online-tools opened up for valuable ways of showing the code, and have that as a basis for discussions. Moreover, a student commented that the controlled communication manners required the speakers to be more well-prepared than before. Student comment: "*Preparing ideas before meetings. That is, ideas are carefully prepared and presented, rather than elaborated on at the online-meeting*."

- *On the negative side*, Miscommunication is riskier in online. It seemed to be extremely hard to solve hard difficulties, which could lead to pointless conflicts. Lack of clarity in communication, among other things due to bad sound-qualities, in combination with non-native English for all students, with nuances in expressions that could be hard to grasp, probably contributed to this. Again, online meetings do not presume spontaneous comments, and do not give valuable support for non-verbal communication, and sketches and drawings, as alternative ways to clarify yourself (see relation to CDIO Syllabus 3.2.6, and 3.2.5). Such examples do especially point out the critical importance of *communication* in itself.

Changing Work Situation

Further discussions concerned a possible change in ways of working. Student comments: *"We may see a future way of working, Cross-country, a kind of game-changer, internationally. Companies may have other possibilities to find talents internationally, they don't have to move, they work from home*". These are of course extremely interesting reflections, that open up for even more reflections from teachers, such as: *What is expected from tomorrow's employee, and from the employer point of view*? *What can an employee require from a hiring company*? *What personalities are expected, or even required, from employers if the game-changer takes place*? *Who, with respect to personality, will benefit from online-environments, who will suffer from it*? *Introverts vs. Extroverts*? Moreover*: There seem to be no sufficient online-tools today. Should we expect white-boards included in online tools of tomorrow*? *A Project Manager must be mentally stable, must be able to avoid pointless conflicts.* If employment forms really will change, students of the current SE2 course are actually well-prepared. Furthermore, there is certainly a reason to study how the discipline of Software Engineering in itself will be affected, according possible new process models, new tools for communication, development, test, and integration.

Finally, yet one important finding is that students now use the programming environment IntelliJ (JetBrains, 2020), to do pair programming in real time and at the same time could ask questions and learn from each other: *"I used pair-programming to learn how the system works, it's just like looking at a YouTube video, the difference is that you can ask questions whenever."* Another student pointed out that pair programming doesn't any longer mean that two persons are sitting in front of the computer screen. Because of the IntelliJ IDEA (JetBrains, 2020) possibilities to have several contributors at the same time (recommended maximum of 5) doing pair programming can consist of more than two persons: *"Pair programming have we used in our subgroup since **three** brains are better than one! "*

SURVEY

A survey was conducted at the end of the course to look at the students' attitude to how well they related to the course under the prevailing circumstances. The discussions during the course, as pointed out in the section above, showed an increasing adaptation to the situation. The survey, on the other hand, shows the condition at the end of the course.

From about 45 students, responses were received from 20 students. The survey was answered anonymously which is reasonable, but which makes it difficult to look at the relationship between the group of respondents and the answers received. For example, if it is mostly the more ambitious students who answer, this can also be reflected in a more positive attitude towards the questions, and the responses to those.

The survey was divided into a quantitative, and a qualitative part. The questions of the quantitative part, as well as the results of the survey can be seen in Figure 5. The conclusion that can be drawn from the results is that students think that it worked quite well to work in the way they did. This applies to the course as such, and communication, as well as technical development.

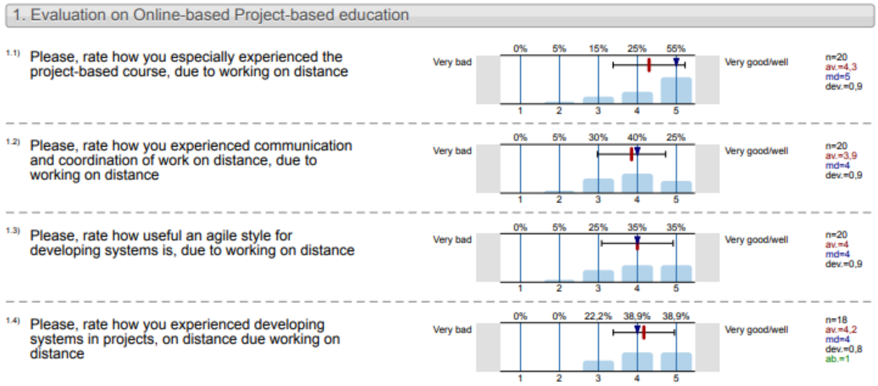

Figure 5. Result of the quantitative part of the survey

The qualitative part was divided up into the questions as stated below. All of those should be seen with respect to the current specific situation. While there are many interesting and contributing answers, well worth further reflections, there is only room here for an excerpt from these. Still, the full material can be found at Einarson & Teljega (2021).

From the teachers' point of view, students' attitudes do not really differ much from previous years, which means that the migration to an online teaching context has not been that dramatic.

1. **What was the most important insight to achieve successful project work?**
   - *To have good communication and to be able to ask questions/discuss with the subgroup. We have achieved success also with pair programming fully remotely.*
   - *Working on distance give a clear view about people's work ethics and how they value responsibility. Not easy to hide behind others.*
   - *Teamwork That it worked better than expected. It is no different setting time schedules for meetings, finishing tasks, meet deadlines and so on than working on site*
2. **Are project meetings and communication in real life-better, more efficient? Why/why not?**
   - *I don't see any difference to be honest. I think that online is my choice because I'm more productive in this way*
   - *I think a combination of both is best. But meeting in real life isn't necessary unless the physical aspect concerning hardware demands it*
   - *yes, easier to not misunderstand each other*
3. **Have you used any agile methods like pair-programming, standup meetings? Why / why not?**
   - *Pair programming: because it can bring a subgroup together. If done right, it can make members understand the code properly.*
   - *Yes, did pair-programming somewhat (screen sharing) as it was easier to get in the working mindset when someone is there forcing you to focus*
   - *Yes, to practice together while making progress*
4. **Have you done your project work physically, digitally or both?**
   - *Both, I have been working with the PM physically to review coming events and to code together. I have also worked physically with hardware centred groups to support and help them. The rest of the communication has mainly been digital.*
   - *Both. We are the physical house group so the name kind of explains that we had to meet in person as well :)*
   - *I have only done it digitally, being part of a group that didn't have to deal with hardware.*

5. **Were there any conflicts in your project group? If Yes, did you solve it and how?**
   - *In the subgroup we didn't have any but in our whole group we did have. I rather not do anything about it if it's not about me*
   - *No, really good team work all along.*
   - *Yes. Big issues. through teachers, project manager and finally we solved it internally*
6. **Anything else that you think is of importance but is not covered in the questions above?**
   - *I think that it is important to keep in mind that no one in the group has worked in a larger group before. It is therefore hard to compare this experience to what it would be if we were working physically together.*
   - *Personally, I loved this course and I enjoyed studying it a lot, except for the first two weeks since we didn't understand what kind of project and requirements the course cover. Thank you for everything and I appreciate your guidance during the past three months.*
   - *Think it was a good survey in all. Thank you! Interesting to work remote and I can only see the benefits prior the negatives. I'm more productive when working remote.*

RELATED WORK

Einarson & Saplacan (2017) shows how the course SE2 and its projects especially correspond to CDIO Standards 7, and 8. In this specific case Standard 6 should also be highlighted, since that standard especially relates to lab workspaces, but here especially interesting since the concept of workspaces rather relates to an effective distributed context. Furthermore, Einarson & Saplacan (2017) addresses a number of points from CDIO Syllabus, within Section 2, 3, and 4, that are clearly regarded through SE2. However, in this particular contribution, we would especially like to highlight Section 3, regarding *Teamwork and Communication*, which has been particularly critical. We can here address several points that are challenging, such as, 3.1.2 *Team Operation*, 3.1.4 *Team Leadership*, and 3.1.5 *Technical (and Multidisciplinary) Teaming*. For the latter, we further exemplify with *Distance, distributed and electronic environments*, and *Technical collaboration with team members*, as especially challenged. Furthermore, non-native *Communications in English*, combined with bad communication links, have led to significant challenges in e.g., 3.2.7 *Inquiry, Listening and Dialog*, 3.2.8 *Negotiation, Compromise and Conflict Resolution*, and 3.2.9 *Advocacy*.

While the upcoming situation due to the pandemic certainly is unique, related work can still be seen regarding online teachings. For instance, Norberg, Stöckel, & Antti (2017) applied Agile time tools found in industry, as a design for a preparatory level course which they moved online and proved that with time tools, students could control their learning and could keep the pace. Their course consists of small number of students which don't know each other, and it is an ordinary length of the course. In this article, we make a further contribution by observing larger groups of students over longer period of time. In contrast, our students know each other at least two years, also they have met physically before the pandemic. Our observations confirm Norberg, Stöckel, & Antti (2017 findings, despite our course consists of a larger sample of students and a longer period between project meetings.

Lucke, Brodie, Brodie, & Rouvrais (2016)'s study is based on many references that have proved that if carefully planned course/program curriculum, and by being prepared to use a flexible way of working, it is possible to adopt CDIO for distance and online education. Our observations motivate that it is possible to keep the quality of CDIO standards when moving the CDIO campus course online, even though it was done rapidly because of pandemic situation. Many new digital tools are born every day which can be used to successfully cover activities that maintains CDIO standards.

CONCLUSIONS

It was, in the name of honesty, with some degree of concern that the teachers approached the course during the situation of the pandemic that arose. At the same time, we could see an interest in how to complete a course, so dependent on a physical location, completely online. The teachers, as well as the students, had to prepare to be patient and flexible before this new situation. All in all, it can be said that the actual outcome of the course was clearly good. That is, the migration from onsite-, to online teaching was not that dramatic. This can be seen as a consequence of that the students (and also the teachers) over time adapted more and more to the new situation, and saw how problems could be tackled in new ways. For instance, agile methods, which are normally related to physical sites, can be partly performed online, and development, integration and testing of technical solutions can be performed distributed.

All in all, the quality seems to have been maintained, with regard to course requirements, as well as to CDIO Standards and Syllabus. This can be concluded through the outcomes of student projects, as well as through the results of the formal course evaluations, and through the teachers' informal reflections. In addition to this, observations have included the fact that we may face a game-changer, where we work more and more online in the future. From such perspectives, the course can be seen as particularly interesting, and contributing to the students and their future work careers, as well as to the teachers' view upon how provide future project-based courses.

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BIOGRAPHICAL INFORMATION

Daniel Einarson has a PhD in Computer Science and has several years of experience in teaching Computer Science and Software Engineering. Furthermore, he has been experimenting with several different forms for project-based learning.

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ON-SITE AND ONLINE COMBINATION FOR STUDENT EXCHANGE PROGRAM

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ABSTRACT

Yeungnam University (YU), South Korea, and Rajamangala University of Technology Thanyaburi (RMUTT), Thailand, have collaborated internationally for a short-term exchange program for students under the project titled Global Capstone Design Project (GCDP) since 2018. Its objectives are to provide students with an actual product design-build-test hands-on experience, to enhance design capability for an Internet-of-Things (IoT) device, to interact with students and faculty from different universities and countries, to develop a global mind-set and effective communication skill, and to improve a global competence through international teamwork. The program consists of 3 phases: (1) a 3-day on-site program 1 for project scoping and planning held at RMUTT, (2) a 6-month online collaboration with coaching supports from both institutions and (3) a 5-day on-site program 2 for project finalizing and presentation held at YU. Ten teams of Thai and Korean students are formed and worked together for 8 months on implementing Design Thinking and creating an IoT product. The team's projects are assessed and awarded at the end of the exchange program. GCDP in 2018-2019 year has finished successfully as planned. However, for 2019-2020, the last phase of the GCDP, which was planned to be held on-site at YU, was changed due to the forbidding of travel to Korea. The activities were re-designed to provide opportunities for the student to finalize and present their projects using an online meeting platform. At the end of program 1 and program 2, student feedback surveys were conducted using an online questionnaire. The results show that the students experienced product design, production, and testing based on their disciplines. They have strengthened their capabilities through the actual product design using design thinking. In addition to improving personal and interpersonal skills when solving engineering problems, they have developed international sense, effective communication skills, and international teamwork skills.

KEYWORDS

International collaboration, design thinking, design-build-test experience, Standards: 5, 8

INTRODUCTION

Internationalization and mobility requires commitments from the institution and study programs to expose students to foreign cultures, promote curriculum transportability, enable qualification portability, encourage joint awards, and support transparent recognition (Campbell and Beck, 2010). CDIO optional standards have been approved by the CDIO council since 2020, pushing the participating institutions to expand their CDIO implementation in wider dimensions regarding the evolving of the engineering education context (Malmqvist et al., 2017, 2020). The description of the internationalization and mobility optional standard is shown below:

> "The institution demonstrates a tangible organizational commitment to internationalization and student mobility. It enunciates the exposure, promotion, facilitation, opportunity and scholarship of an internationalized curriculum, qualifications and international mobility of students. Curricula which prepares engineers for a global environment and exposes them to a rich set of international experiences and contexts during their studies. Student learning outcomes include attributes and competencies which are recognized through international accords. Authentic cultural awareness learning experiences are embedded within the curriculum or social activities. Opportunities are made available for students to learn second and third languages. Studying abroad and other international experiences (including internships, exchanges) are encouraged and recognized for credit. Institutional cross-credit for study abroad is transparent. The institution establishes partnerships with international universities, benchmarks programs internationally and is actively involved in international engineering education scholarly activities."

Even prior to the release of CDIO optional standards, there have been a number of international collaborations among CDIO institutional members. Exchange activities are in wide range; for example, student and staff exchange, workshops, camps, internship, co-operative education, credit-transfer program, double-degree program, joint-degree program, and joint research. When preparing the institution to pursue internationalization, Salti et al. (2019) advised 3 phases of pre-institutionalization, institutionalization, and post-institutionalization. The pre-institutionalization requires the understanding of policies, the involvement of stakeholders and funding identification. The institutionalization phase needs an internationalization structure with details of activities and mechanism for the implementation. The post- institutionalization phase involves knowledge sharing lessons of good practices, scales up and sustains the positive outcomes.

A number of literatures shared successful international collaboration activities, contributing the benefits and challenges as learning lessons for others. Säisä et al. (2020) described the international cooperation model between two project offices; "theFIRMA" at Turku University of Applied Sciences (TUAS), Finland and AGILE@SoC at Singapore Polytechnic, Singapore as learning environments that encourage hands-on learning activities with industry paid projects. Hokkaido Information University, Japan and Rajamangala University of Technology Thanyaburi (RMUTT), Thailand have evolved their international collaboration with more exchange programs in ICT-based international workshops. A successful outcome of web design contest resulted in involving more students, faculty members and staff and expanding to short film contest and computer programming contest within 10 years (Anada et al., 2018). Not only does the student develop personal skills; critical thinking, creative thinking, problem solving, but they also progress in interpersonal skills in team working, communication and communication in English language (Rian et al., 2019). With the Erasmus Lifelong Learning Program, European universities organized numerous international intensive projects across the region. The students collaborated in multi-disciplinary teams with project-based learning experience to solve engineering problems in a CDIO context. The projects provided chances to deepen and strengthen partnership between universities, enhancing opportunities for future collaboration in curriculum and course design within the international context (Piironen and Karhu, 2017).

This paper aims to share how Yeungnam University (YU), South Korea and Rajamangala University of Technology Thanyaburi (RMUTT), Thailand:

(1) Co-create a student exchange program “Global Capstone Design Project”.
(2) Provide both onsite and on-line experiences to participating students.
(3) Evaluate the program for future improvement.

INTERNATIONAL COLLABORATION

RMUTT, Thailand and YU, South Korea started their international collaboration in 2015 after representatives from both universities met in the 2014 CDIO Asian Regional Meeting in Kanazawa, Japan. From 2015-2018 academic years, YU invited RMUTT students to participate in the International Capstone Design Project (ICDP) Camp hosted by Hub Center of Engineering Education (HCEE). Each year, around 60 students from South Korea, Japan, Singapore and Thailand were involved in a one-week intensive camp. The theme of ICDP was to design, build and test autonomous electric vehicles, with the main objectives to (1) promote teamwork among international students, (2) improve communications skills among international students, (3) enhance problem solving capabilities on complex real engineering problems, and (4) enhance multidisciplinary design, design thinking and making capabilities. Figure 1 demonstrates ICDP activities in the past from 2015-2018.

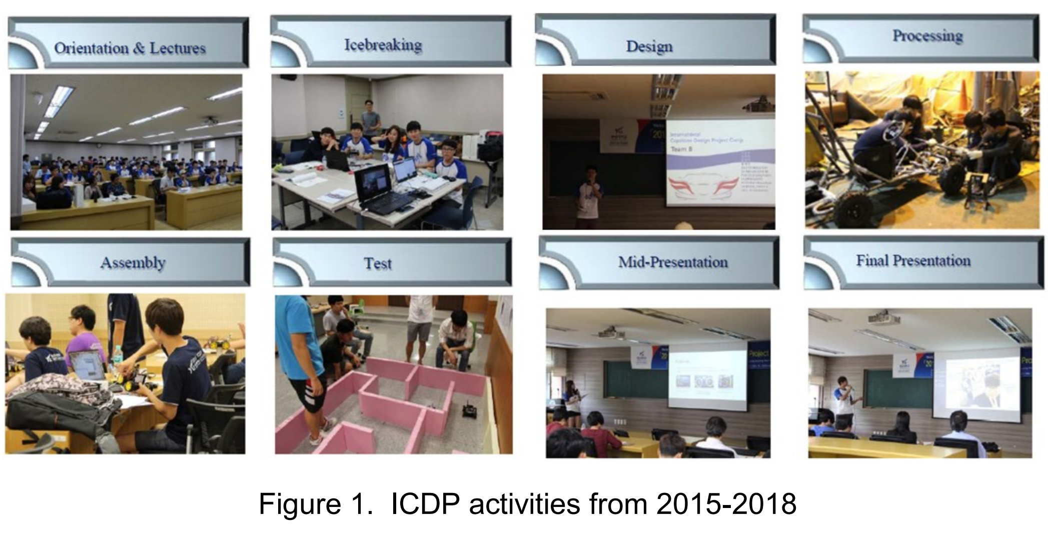

Figure 1. ICDP activities from 2015-2018

At the end of 2018 ICDP, RMUTT and YU have initiated a new model for international collaboration with a new pursuit: for two-way student and staff mobility compared to 1-way mobility of ICDP. This two-way mobility program consists of 3 phases as shown in Figure 2:

(1) A 3-day on-site program 1 for project scoping and planning held at RMUTT.
(2) A 6-month online collaboration with coaching supports from both institutions.
(3) A 5-day on-site program 2 for project finalizing and presentation held at YU.

The C-D-I-O (Conceive-Design-Implement-Operate) concept was applied when the organizer planned the activities, so that the students could experience the emerging context of the engineering profession nowadays.

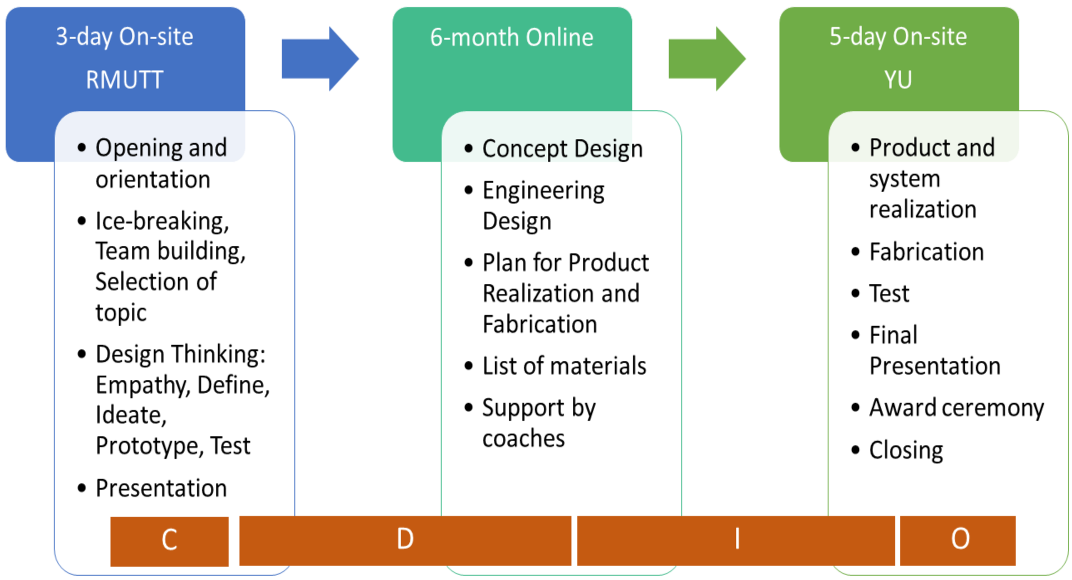

Figure 2. GCDP Student Exchange Program

The new model is called a Global Capstone Design Project (GCDP). With an emerging technology, GCDP focuses on the implementation of Internet-of-Things (IoT) along with Design Thinking and Engineering Design techniques. The objectives of GCDP consist of

(1) Providing students with an actual product design-build-test hands-on experience.
(2) Enhancing design capability for an Internet-of-Things (IoT) device.
(3) Interacting with students and faculty from different universities and countries.
(4) Developing a global mind-set and effective communication skills.
(5) Improving a global competence through international teamwork.

Phase 1: On-site RMUTT Design Thinking and Project Scope

Phase 1 is scheduled in January right after the New Year holiday, where Korean students will transfer to Thailand to meet their Thai team members. There are a total of 10 teams of 7-8 students with equal numbers of Korean and Thai students. The students are from different disciplines; engineering, design, computer science, information technology, and technical education. The engineering students come from different majors; automotive, aeronautic, computer, design convergence, electronic and electrical, food, industrial, mechanical, network, robotic. HCEE is responsible for arranging multi-disciplinary groups. The key objective of phase 1 is to guide the student through the Design Thinking process; namely, Empathy, Define, Ideate, Prototype and Test.

A 3-day intensive workshop encourages the students to work intensively from 9 am to 6 pm to generate the project ideas. The detailed program is shown below:

Day 1:

- Opening ceremony and orientation of the program by the local host to welcome everyone, explain the history of collaboration and the program in general.

- Ice-breaking and team building activities led by the local host.
- Lecture by HCEE professor on Design Thinking.
- Group work facilitated by coaches: The students can discuss and agree on a topic they are interested in working on.

Day 2

- Group work facilitated by coaches: The students interview potential users of their projects. The information is then used to define a user need statement. The teams ideate several ideas, summarize an initial concept and make prototypes.

Day 3

- Group work facilitated by coaches: The students prepare their presentation.
- Presentation: The students present their prototype along with the test results with their potential users. After each presentation, there is a 5-minute question and answer available for feedback and clarification of the project.
- Lecture on Project Management by RMUTT professor to guide the students for the upcoming online collaboration and progress reports with team coaches before meeting again at Phase 3.

Phase 2: Online (Remote Collaboration)

Phase 2 is scheduled from January to June with 2 milestone checkpoints to assure continuous collaboration remotely. Faculty members from both institutions are assigned to be coaches for each team. The first check-point is in March, followed by the second check-point in May. The students work remotely to finalize the concept after receiving feedback from users, generate engineering design, plan for a real fabrication at Phase 3, list all materials needed and submit the list to HCEE. At each check-point, the students and coaches arrange an online synchronous meeting. The students present their team progress and receive feedback from coaches.

Phase 3: On-site YU Project Finalization and Presentation

Phase 3 is scheduled in July, now Thai students' turn to visit South Korea. A 5-day intensive workshop focuses on product realization through fabrication hardware, complete software, check on hardware-software integration and testing. The final presentation is the key event, where the groups show how their product works in a real life setting. To celebrate these great achievements of the students, different categorical awards are given to all teams, along with certificates of participation at the closing ceremony. Figure 3 shows the whole journey of the GCDP model. Figure 4 displays photos of phase 1 and phase 3 events.

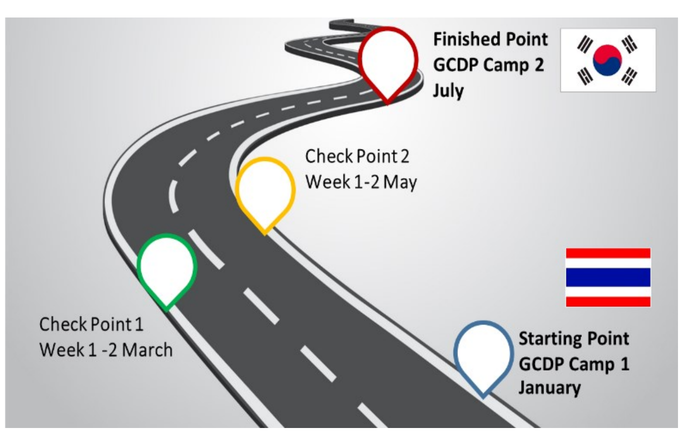

Figure 3. GCDP Journey

Figure 4. GCDP Phase 1 at RMUTT and Phase 2 at YU

EVALUATION

GCDP in the 2018-2019 academic year had finished successfully as planned. However, for 2019-2020, the last phase of the GCDP, which was planned to be held on-site at YU, was cancelled due to the forbidding of travel to South Korea. The activities were re-designed to provide opportunities for the students to finalize and present their projects using an online meeting platform.

At the end of Phase 1 and Phase 3, student feedback surveys are conducted using an online questionnaire. There are 4 parts of the questionnaire; (1) Basic information on gender, university, major and year of study, (2) An open-ended question asking what the student expect to improve most in this program, (3) A 5-scale rating score asking the student to rate the importance of the program goals, (4) A 5-scale rating score asking the student to rate the student achievement and (5) An open-ended question for the student feedback of the program.

There were 74 students in 2018-2019 and 73 students in 2019-2020 responded in the questionnaires. Figure 5 shows distributions of basic information for 2018-2019 and 2019-2020 participants. In 2018-2019, there were 71% male and 29% female students. In 2019-2020, there were 81% male and 19% female students participating in the GCDP. The majority of participants were 3rd year students with 64% in 2018-2019 and 71% in 2019-2020.

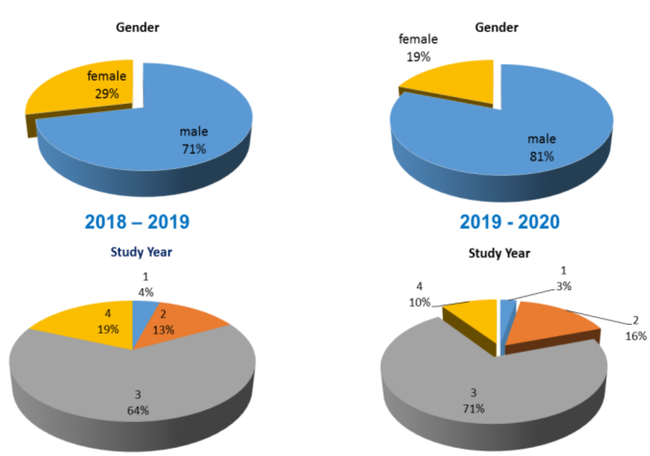

Figure 5. Gender and Study Year of Participating Students

Section 3 of the questionnaire asked the respondents to give a 5-scale score on the importance of their goals to participate in GCDP. The scales are 5-extremely important, 4-very important, 3-important, 2-not important, and 1-not important at all. Figure 6 displays average scores of pre-program and post-program data from 2018-2019 and 2019-2020. “Experience actual product design, build, and test with major knowledge” received a highest score, becoming the top rank, followed by “Solve engineering problems and collaborate in engineering design” as a 2nd place. “Improve global competencies through international teamwork” was the 3rd rank. It is obvious that in the post-program, average scores were higher than the pre-program scores, except the “Exchange with participating professors and students from other universities” and “Improve global competencies through international teamwork” on 2019-2020 due to the change to online which prohibited on-site collaboration.

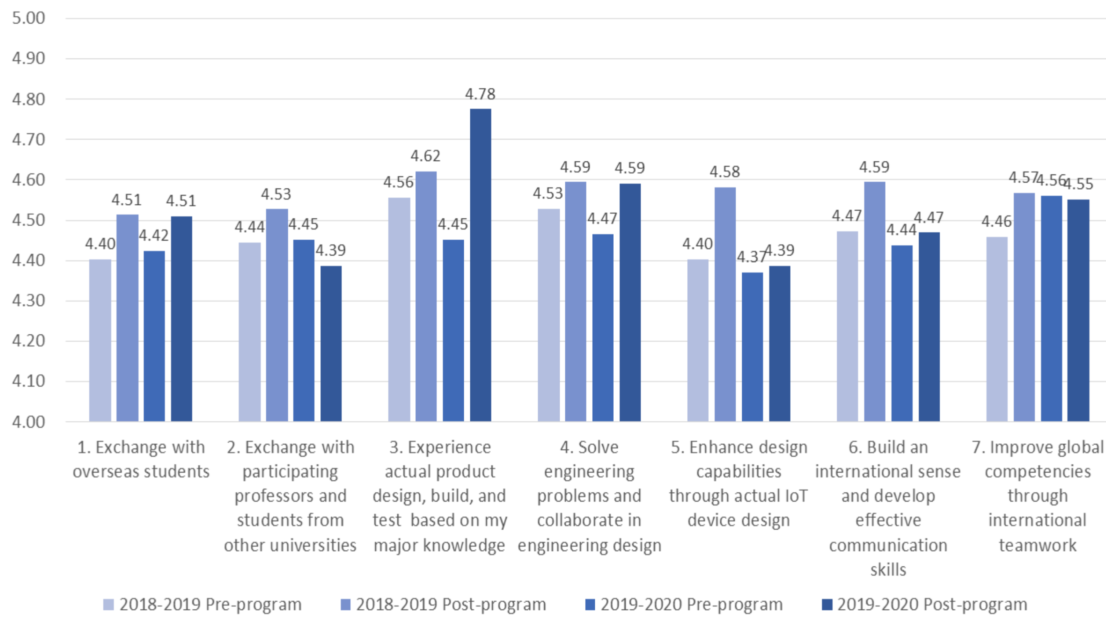

Figure 6. Pre- and Post-program Data on the Importance of Goals

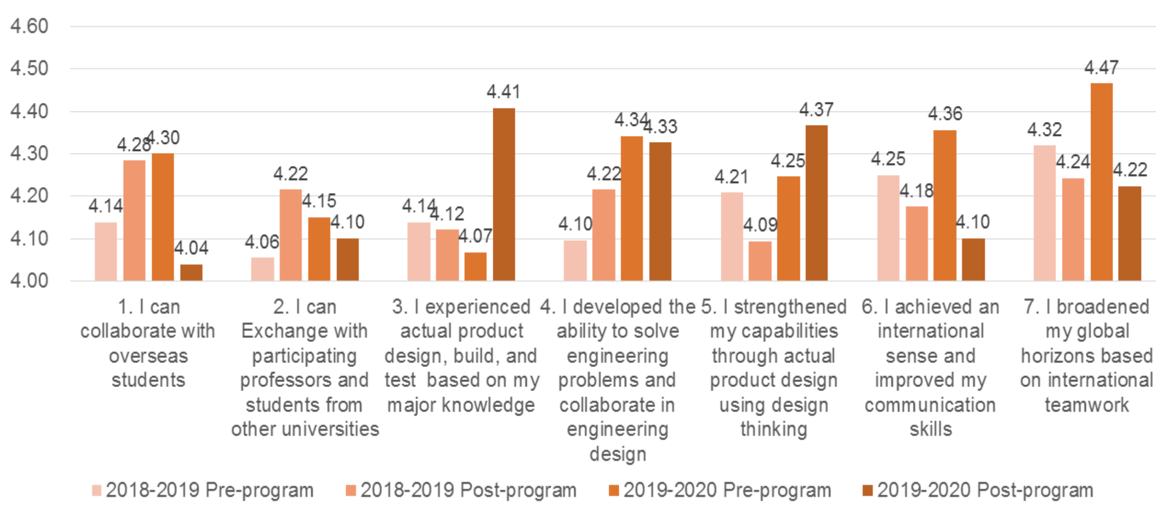

Figure 7. Pre- and Post-program Data on the Achievement

Section 4 asked the respondents to self-evaluate how much they achieved. The scales are 5-totally agree, 4-somewhat agree, 3-agree, 2-somewhat disagree, and 1-disagree. Figure 7 demonstrates the average scores of pre-program and post-program for both 2018-2019 and 2019-2020 events. "I broadened my global horizons based on international teamwork" was in the top rank of the achievement. However, when looking at the post-program achievement in 2019-2020, there were lower scores in achievement number 1, 2, and 6. This was due to the change from on-site to online because of the travelling prohibition, disabling participants to collaborate and exchange ideas face-to-face. However, achievement number 3 and 5 show higher scores because the completion of the project and the overcome of challenges during those 7 months.

Student Feedback

Section 5 asked the students to give feedback to the program. The student gained experiences in improving their disciplinary knowledge, personal and interpersonal skills and widen their international perspectives. Examples of their feedback are below:

"Taking a program on the theme of design thinking, as an engineer, was able to understand the idea of a designer, and it became an opportunity to broaden the perspective of thinking. In addition, since I had to make one high-quality IOT device, the ability to automatically produce coding and hardware improved."

"By sharing opinions with overseas students, we were able to conduct the Capstone program from various perspectives."

"It was a meaningful time for me to participate in long-term team projects, to improve my communication skills, improve my communication skills, solve engineering problems, and improve my teamwork skills."

"Although the language spoken with foreign students is different, it seems that I have gained a good experience to communicate as an engineering student."

"It seems that I gained a global perspective by working on a project on the same social issues as students from other countries."

Teacher Perspectives

The GCDP implemented the CDIO concept to provide experiences to the students to practice engineering problem solving [CDIO Syllabus 2.1] and engineering design in the multidisciplinary team-based environment [CDIO Syllabus 3.1], so they are granted opportunities to improve their interpersonal skills, as well as using English as a medium of communication [CDIO Syllabus 3.3.1]. Throughout 7 months, the students practice and develop their "conceive – design – implement – operate" skills [CDIO Syllabus 4.3-4.6] and project management skills [CDIO Syllabus 4.3.4]. Moreover, students experience a different working environment. On-site workshop enables face-to-face communication and team bonding opportunity, while online working is more flexible in time and resource management. Even with the pandemic situation causing initial plans to change, the students have still developed strong learning attitudes [CDIO Syllabus 2.4].

The GCDP employed CDIO Standard 5 which provide design-implement experiences to students working in projects. The GCDP activities based on active experiential learning methods [CDIO Standard 8] which engage students to think, generate ideas, solve problem and encourage professional engineering practice. Moreover, the participated teachers as coaches to the student teams viewed GCDP as a great opportunity for enhancing faculty competence [CDIO Standard 9] to share their expertise, communicate in foreign language and practice their coaching skills. GCDP was a good start for future expansion of the collaboration between instructions, for example, on-the-job training, cooperative education and research. The challenge that both students and teachers encounter was the language barrier which slowdown or sometimes discourage the student to work effectively. The reassurance from coach and team member can help overcome this challenge.

CONCLUSION

The GCDP project promotes internationalization, student and staff mobility. The survey results show that the students have experienced a product design, production, and testing based on their disciplines. They have strengthened capabilities through the actual product design using design thinking. In addition to improving personal and interpersonal skills when solving engineering problems. They have developed an international sense, effective communication skills, and broaden their horizon based on international teamwork.

The 3rd year of GCDP in 2020-2021 academic year started in January 2021. With the travelling restriction, the organizer plans to hold the events fully online. Activities are, again, redesigned to accommodate this challenging situation. The authors plan to share the outcome of the next GCDP in the near future.

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PROJECT-BASED LEARNING IMPLEMENTATION - COLLABORATION BETWEEN UNIVERSITY AND INDUSTRY

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ABSTRACT

This paper presents two experiences of collaboration between university and industry through the implementation of the Project-based Learning (PBL) model in the University of Navarra. One of them has been developed by third year students of the Industrial Management Engineering Degree, and the participation is voluntary. The other one is carried out by students of the Master of Industrial Engineering, and it is mandatory. In both cases, the students visit a company, and it is the enterprise that poses them a challenge to solve or a project to be developed. After working in groups for several weeks, students present their project to the company managers. The main objective of this paper is to examine the benefits of developing PBL in a company context. It also aims to analyze the development of students' skills, motivation and commitment in comparison with other similar activities where the problem to be solved is defined by the teachers. It pretends as well to know the opinion of the enterprises regarding the university-industry collaboration and the work done by the students. The students value this experience, in both cases, positively, as it allows them to work on a real case, in which they test their knowledge and capabilities. The companies also appreciate this experience, as it is valuable for them. Apart from all the advantages that active learning methods entail for students, developing it in the context of university-industry collaboration leads to many other benefits. We have verified that when the project consists of solving a real problem proposed by a company, the engagement and motivation of students increases. Moreover, this experience provides a rich learning environment, closer to what their professional life will be.

KEYWORDS

Project-based learning, university-industry collaboration, Standards: 2, 3, 7, 8, 9

INTRODUCTION

Nowadays the job market is in a continuous change. This demands to the future professionals the capacity of developing a continuous learning and adaptation to the new requirements. Higher education must promote deep content knowledge but also professional and personal skills that allow students to face professional life. Wager (2008) enumerates what he calls "the seven survival skills": critical thinking and problem solving, collaboration and teamwork, agility and adaptability, initiative and entrepreneurship, effective oral and written communication, curiosity and imagination. Other attitudes like honesty, social responsibility and professional ethics must be promoted as well. In the context of Engineering Education, The CDIO Syllabus, in addition to learning outcomes for technical disciplinary knowledge, specifies learning outcomes as personal and interpersonal skills, and product, process, and system building (CDIO, standard 2). Crawley et al. (2011) point out the Syllabus which can be described as an adaptation of the UNESCO framework (Delors et al., 1996) to the context of engineering education. Engineering accreditation bodies like EUR-ACE (2008) and ABET (2018) identify as well the need of reinforce transversal competences.

Higher education is incorporating new methodologies that facilitate students developing professional skills at the same time that acquire deep content knowledge (Smith et al, 2005) "Active learning methods engage students directly in thinking and problem-solving activities. There is less emphasis on passive transmission of information, and more on engaging students in manipulating, applying, analyzing, and evaluating ideas." (CDIO, standard 8).

Project-based learning (PBL) is one of the pedagogical approaches that can be particularly useful in the CDIO design-implement courses (Edström & Kolmos, 2012). In this method, students develop a project or investigate solutions for a problem. It gives students the opportunity to do something closer to what is done in real professional life, facilitates students to apply their knowledge, helps them to connect key concepts and develop creativity and critical thinking, often in a collaborative and interdisciplinary context (CDIO, standard 7).

Collaboration between university and industry is beneficial for the teaching-learning process in higher education, especially for technical degrees, as their graduates probably will end up working in industries. The creation of opportunities for students to interact with industrial companies is a way to contribute for the development of the students' competences (Mazini et al., 2018). Different kind of activities such as visits to enterprises and factories, invited talks or master classes by industrial experts, internships in companies, development of final degree or master theses in enterprises, etc. can be organized to approach the students to the "real wold". Diaz et al. (2013) assessed the efficiency of the most common teaching-learning activities in collaboration between academia and industry in terms of success vs. implementation cost and success vs. implementation time and concluded the beneficial effects of PBL activities and of students' taking part in real projects for developing their final degree theses. This methodology allows students to apply what they have learned in classrooms to real challenges instead of problems proposed by teachers. It is very enriching for students to experience the limitations of theories learned in class, the necessity of adapting models to real situations and requirements, etc. Moreover, these kinds of activities are not only beneficial for the teaching-learning process, but also for the company as the students can contribute to the enterprise innovation (Buser, 2013).

This paper describes and analyzes two experiences of collaboration between university and industry through the implementation of the PBL model, in undergraduate and master's

students. In both cases, the students visit a company, and it is the enterprise that poses them a challenge to solve or a project to be developed. The objectives of this work are:
1) To explore students' perception of their skill development, motivation and engagement using PBL activities in the context of a company compared to other similar activities where the problem to be solved is defined by the teachers.
2) To know the opinion of the enterprises regarding the university-industry collaboration and the work done by the students.

In the methodology section, we describe the experiences' development, their phases and surveys conducted by the students and enterprises. We summarize the main results obtained from the surveys in the results section and finally, we point out the most relevant conclusions that are derived from the study.

RESEARCH METHOD

This research has been carried out with the students from the University of Navarra, particularly with the Engineering School (Tecnun) students. The degree and master's curriculums are designed in such a way that the practical part of the subjects is obtained through laboratory practices, work designed by the professor himself, visits to companies, teaching by guest professors from companies, etc. However, in an internal and external analysis carried out in 2018, a weakness that came to light in this curriculum was "the scarce contact of students with real companies".

In project-based learning, students work in groups to solve challenging problems that are authentic, curriculum-based and often interdisciplinary (Solomon, 2003). Getting students to work on real business projects also allows students to connect what they learn in class with real business experience (Biedermann et al., 2017). Therefore, if we can get the students to work on a real project facilitated by the company, the students will be able to better assimilate the knowledge taught in class.

In order to implement this project, it has been decided to have one experience in a degree not linked directly to any specific subject and another in a master program directly linked to a specific subject.

Degree Project

This project has been carried out in a machine tool company. This company delivers value-driven engineered solutions for their customers' manufacturing needs, becoming their partners for advanced productivity systems.

As mentioned above, the work is not directly related to any subject. Participation is voluntary and the objective of the activity is to perform a team project that solves a challenge proposed by the company. Students visit the company and have the opportunity to learn about its activity, processes, products and markets. During this visit, one of the managers presents them a challenge that has to be solved in 6-8 weeks. The challenge can be related to different topics: quality, production, people management, sales, etc. To better understand the challenge, students receive information and data. After working in groups for several weeks, students present their project to the company managers, who decide which is the best proposal. The students that have developed the selected proposal receive a diploma and a cash prize.

Master Project

On the other hand, the project that is carried out among the students of the Master of Industrial Engineering is developed within the subject "Automated Manufacturing Systems and Industrial Robotics ". In this case, the company proposing the project is part of one of the largest machine tool groups in Spain and they are world leaders in blade grinding machines used on aircraft engine rotors.

The project consists of the design of a machine for the manufacturing of an industrial component, such as a railway axle or a tubular connection for the oil and gas industry. In order to reinforce students' understanding of the machine design process, students visit the company and specific sessions related to precision engineering and manufacturing automation are given by engineers of the company. This gives students opportunities to learn how the industry faces real-life problems and to realize the connection between the technical content they are learning at the university and the real work. Finally, students make an oral presentation of the developed projects to the company's engineers.

Surveys

In order to respond to the objectives proposed in the Introduction, the questionnaire proposed by Biedermann et al. (2017) has been adapted to the context of these projects. Those questions that referred to a specific activity have been modified (e.g., "The company has been able to provide the key aspects to be applied to the design of the brand" has been changed to "The company has been able to provide the key aspects to develop the project"). The first questionnaire designed for the students aims to collect a comparison between this project that they have carried out with a company and other projects that they have carried out throughout their studies at the university. In this way, not only can we see that the PBL is a good option for improving the skills of our students, but it is also better than traditional projects.

On the other hand, with a second survey, we have asked those responsible for projects in companies about their satisfaction with these projects. The respondents were asked to indicate the extent to which they agreed or disagreed with these statements.

In both surveys, a five-point Likert scale was used (1 represented "strongly disagree" and 5 represented "strongly agree").

Table 1 shows the items in the questionnaire, related to the competences acquired during the project (C*), the content of the activity carried out (A*), the collaboration provided by the company (B*) and the motivation they have experienced when carrying out the work (M*). In addition, the students were asked about the reasons that motivated them to participate in the challenge, in the case of the Degree project, which participation is voluntary, and about the positive aspects of the project in the case of the master project, within the subject Automated Manufacturing Systems and Industrial Robotics.

On the other hand, with a second survey, we have asked those managers responsible for projects in companies about their satisfaction with these projects. Table 2 shows the items for this survey to company managers.

Table 1. Questionnaire items (students)

Competencies	
C1	Capacity for analysis and synthesis.
C2	To develop my social skills, leadership and communication skills
C3	To increase my responsibility at work with the group
C4	Ability to manage information
C5	Ability to apply knowledge to practice
C6	Decisions making
C7	To increase my capacity to generate creative and innovative ideas.
C8	To increase my ability of creative thinking
C9	To increase my ability to work in team
C10	To increase my ability to solve problems
C11	To acquire basic skills for my profession
Activity	
A1	The activity has served to meet the needs of the company(ies)
A2	The activity has helped me develop my personal and professional skills
Collaboration	
B1	The company has been able to provide the key aspects to be applied to the project
B2	This type of activity helps me to show potential business needs
B3	This type of activity is a good way for bringing companies closer and gives the possibility to cooperate with them
Motivations	
M1	The possibility that my project is implemented in the company
M2	The fact that my project competes against others
M3	To experience similar to professional life situations
M4	The possibility to include a real project to my CV
M5	Dealing with a real problem
M6	I am encouraged to consider the possibility of starting my own business in the future
M7	To take part of an active learning process.

Table 2. Questionnaire items (managers)

Competencies	
C1	Capacity for analysis and synthesis.
C4	Ability to manage information
C5	Ability to apply knowledge to practice
C6	Decisions making
C11	To acquire basic skills for their profession
C12	To concern about the quality
Activity	
A3	The activity is an added value for the training of the students
A4	The activity has brought value to the company
A5	I would like the approach of this activity to be repeated in other subjects
A6	This type of activity helps to show students potential business needs
A7	This type of activity is a good way of bringing companies and university closer and make them both to cooperate

Collaboration	
B4	Students have been able to make the appropriate questions to extract key information to develop the project
B5	Students have been able to interpret the key issues to be applied to the project
B6	Students have contacted us to solve their doubts
B7	I would have liked to have more meetings with students

RESULTS

In the case of the degree project, a total of 37 students had participated over two last academic years (2018 and 2019). A total of 16 students responded to the survey, that is a response rate of 43 percent. This is considered acceptable given the response rate of similar studies. As can be seen in Table 3, all items score higher in the case of the in-company project than in the case of traditional projects, in subjects, except for item M6 (I am encouraged to consider the possibility of starting my own business in the future). This could be explained by the fact that students in this degree have specific projects related to entrepreneurship, within some of the subjects of the degree. Those difference are statistically significant for most of the items (paired t-test, $p < 0.05$). The small sample size (16 responses) may explain that not all the items are statistically significant. Furthermore, all the items score above 3.5, which indicates that the project developed in the company is highly valued both in relation to the competencies acquired, to the activity itself and to the collaboration with the company and to the motivation they have in general to carry out the project.

In the case of the master project, a total of 54 students participated in the last academic year (2019). A total of 42 students responded to the survey, that is a response rate of 78 percent. As can be seen in Table 3, all items score higher in the case of the in-company project than in the case of traditional projects. Furthermore, all the items score above 3.5 except for item M6, which indicates that the project developed in the company is highly valued in relation to the competencies, the activity, the collaboration with the company and the motivation. The smallest differences in the scores correspond to items C4 (Ability to manage information) and M6 (I am encouraged to consider the possibility of starting my own business in the future). Those differences are also statistically significant for most of the items (paired t-test, $p < 0.05$).

When the students were asked about the aspects that they would highlight from the challenge, their answers were very similar in both degree and master students. The answers were related to the fact of being a different activity, working with a real case of a company and seeing its application. Moreover, the students remarked positively the idea of exposing their solution to the company, receiving feedback from managers and competing against their mates. The students also consider that this type of projects is very useful for preparing them for their future job, in which the problems of the companies arise in very different ways and are not easy to solve. In the case of the master students, they also pointed out working in a multidisciplinary project applying theoretical knowledge to practice.

Table 3. Paired t test of assessment of attributes between traditional and company project

	Degree (n=16)			Master (n=42)		
	Traditional project mean (SD)	**Company project mean (SD)**	**p-value**	**Traditional project mean (SD)**	**Company project mean (SD)**	**p-value**
C1	3.500 (0.894)	3.688 (0.946)	0.485	3.452 (0.593)	4.071 (0.513)	0.000**
C2	3.500 (1.095)	4.000 (0.966)	0.040*	3.524 (0.740)	4.143 (0.718)	0.000**
C3	3.813 (0.981)	3.938 (0.929)	0.652	3.619 (0.731)	4.095 (0.692)	0.000**
C4	3.563 (0.727)	3.563 (1.263)	1.000	3.524 (0.671)	3.881 (0.739)	0.017*
C5	2.875 (0.885)	3.938 (1.181)	0.012*	3.524 (0.740)	4.524 (0.634)	0.000**
C6	3.688 (1.014)	4.125 (0.957)	0.048*	3.500 (0.707)	4.214 (0.645)	0.000**
C7	3.313 (1.078)	4.250 (0.856)	0.003**	3.214 (0.898)	4.357 (0.821)	0.000**
C8	3.188 (0.911)	4.188 (0.981)	0.000**	3.310 (0.950)	4.143 (0.751)	0.000**
C9	4.000 (0.966)	4.313 (0.946)	0.206	3.929 (0.894)	4.119 (0.772)	0.103
C10	3.313 (1.014)	3.750 (1.000)	0.089	3.643 (0.759)	4.048 (0.795)	0.000**
C11	3.750 (0.856)	3.875 (1.088)	0.633	3.524 (0.804)	4.071 (0.745)	0.000**
A1	2.500 (0.816)	4.313 (0.873)	0.000**	2.976 (0.841)	4.262 (0.734)	0.000**
A2	3.500 (0.966)	4.000 (0.966)	0.056	2.500 (1.042)	4.452 (0.803)	0.000**
B2	2.875 (0.885)	4.375 (0.806)	0.000**	2.595 (1.106)	3.976 (0.869)	0.000**
B3	3.000 (1.033)	4.563 (0.629)	0.000**	3.595 (0.857)	4,119 (0.803)	0.000**
M1	2.313 (1.078)	4.063 (1.181)	0.000**	2.452 (1.087)	4.000 (1.059)	0.000**
M2	3.375 (1.088)	4.188 (0.981)	0.005**	3.286 (1.111)	4.143 (0.843)	0.000**
M3	2.875 (0.719)	4.313 (0.793)	0.000**	3.190 (0.917)	4.381 (0.764)	0.000**
M4	2.563 (1.504)	3.500 (1.506)	0.030*	2.333 (1.097)	3.333 (1.337)	0.000**
M5	2.813 (0.911)	4.063 (1.124)	0.194	3.071 (0.973)	4.190 (0.773)	0.000**
M6	2.563 (1.209)	2.500 (1.414)	0.827	2.548 (1.064)	2.881 (1.194)	0.029*
M7	3.500 (0.894)	3.688 (1.250)	0.509	3.476 (0.804)	3.952 (0.795)	0.000**

* p<0.05
** p<0.01

The results of the survey to the managers were quite high, in most cases above 3.5. In both companies, two managers answered the survey. Table 4 shows the mean value for each company.

The results obtained in the two companies are similar except for items A5 and B7. In the case of item A5, we ask about the possibility of repeating this experience in other subjects. A possible reason for the low value in the case of the master may be that the project is designed to solve a specific problem to a particular subject, so it would not make sense to repeat this experience in other subjects. In the case of B7, managers were asked about having more meetings with the students throughout the project. In the case of the degree, they consider that the students were self-sufficient enough to develop the project in a satisfactory manner without the company managers.

Table 4. Response of projects' managers

	Mean (Degree)	Mean (Master)
C1	4	4.5
C4	3.5	3.5
C5	4	4.5
C6	4	4.5
C11	4	4
C12	3	3.5
A3	4.5	4.5
A4	4	4.5
A5	4	2
A6	5	3.5
A7	4.5	4.5
B4	5	3
B5	4	3.5
B6	3.5	4.5
B7	2	4.5

CONCLUSIONS

The two experiences carried out with undergraduates and masters' students have allowed us to analyze how students perceive that PBL helps to improve their skills. In addition, students positively value the fact that the project is developed in a company's environment, knowing its challenges and working on real projects.

It is also worth noting the difference between this type of project and those proposed by teachers in traditional projects. In all cases, the score has been higher in the challenges posed by the company with the exception of the item related to entrepreneurship in the case of students of engineering degree in industrial organization. As mentioned above, these students have taken courses and developed projects directly related to entrepreneurship.

Finally, it should be noted that the students have felt positive towards the approach and that these experiences have brought value to the companies (item A4).

These results encourage us to continue promoting collaboration between the university and the company in our degrees and masters that favors the stakeholders involved: university, students and companies.

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THE IMPLEMENTING OF CDIO CONCEPT IN THE NKRAFA

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ABSTRACT

The objective of this paper is to illustrate whether implementing the CDIO concept in the Navaminda Kasatriyadhiraj Royal Air Force Academy (NKRAFA) can result in better air cadet performance. Traditionally, the air cadets learn UAVs through several activities including in-class learning, practical training, and also joining such UAV competitions as NKRAFA UAS Contest. However, they could find solutions only for simple missions. The CDIO notion, therefore, was employed in the academy via curricular planning using problem-based learning. The concept has been implemented in the institute since 2015 through the tasks imitated from the actual UAV missions operated by the Royal Thai Air Force. After implementing the CDIO concept, the air cadets can better develop their strategies, as well as form their teams for joining competitions both domestically and internationally. Consequently, utilizing the CDIO concept can result in better air cadet performance regarding UAVs' mission planning. Implementing the CDIO principle can also establish the foundation of the student-learning method that could be more developed in other fields in the future.

KEYWORDS

Air Force, Unmanned Aerial Vehicle, Military Doctrine, Behavioral Change, Standards: 1, 2, 3, 5, 6

INTRODUCTION

Recently, Unmanned Aerial Vehicle (UAV) has been widely used in many domains e.g. freight transport, telecommunication, precision agriculture, military, and so on. It normally refers to a pilotless aircraft that can be deployed on missions that are considered too dangerous for pilots to operate or ones that overcome regulatory concerns. UAVs were originally developed and used for military purposes (Vacca and Onishi, 2017). The first generation of UAVs was "Ariel Target" in 1916. After that, many remote-controlled aircraft followed. With the advancement in technology, there is a growing interest in utilizing UAVs for military missions. It is considered a combat machine that can be used to reduce the risk of the crew. In the first generation, it was more like a surveillance aircraft. However, UAVs today are dangerous weapons that can carry aircraft ordnance such as missiles, or bombs and are used for drone strikes. Moreover, UAVs often carry out tasks that are more difficult and dangerous because of their agility with no life on board to concern with. The flight of UAVs may operate with various degrees of autonomy: either under remote control by a human operator or autonomously by onboard computers. This makes them easy to use and they are allowing researchers to complete challenging tasks with few simple steps. Therefore, the use of UAVs has gained popularity among educators and researchers around the world in recent years (Freeman & Freeland, 2019)

Navaminda Kasatriyadhiraj Royal Air Force Academy (NKRAFA) is an academy in which air cadets are educated and trained to produce commissioned air officers with knowledge, ability and military leadership for the Royal Thai Air Force (RTAF). The institute's curriculum covers both academic and military studies including theoretical and practical aspects, following the needs of the RTAF especially in the field of aviation (Jantarachotigul, 2020). Thus, an excellent educational framework is required for implementing along with the curriculum so that the air cadets can deal with problem-solving more efficiently and effectively. To this end, the principle of CDIO was brought to test in the NKRAFA's curriculum by firstly introducing in UAV mission training, which is one of key policies of the RTAF. Thus, this paper aims to illustrate whether the implementation of the CDIO concept in NKRAFA can result in better problem-solving performance of the air cadets. The rest of the paper describes the pre- and the post- CDIO concept utilization with the conclusion in the end of the paper.

PRE-IMPLEMENTATION OF CDIO CONCEPT

Before 2014, the UAV concept was delivered to air cadets via class lectures and in-class activities. However, the number of participants in the UAV class was restricted since only 2 out of 7 academic departments offered courses regarding UAVs; Aeronautical Engineering and Mechanical Engineering Department. While the rest rather emphasized other study areas, e.g. Civil Engineering, Industrial Engineering, Computer Science, and Material Science. Meanwhile 2014, UAVs have been received more attention from the RTAF as seen from an introduction of the policy that encourages UAV applications by funding and supporting missions for which UAVs were researched and developed (Royal Thai Air Force - RTAF, 2014). As a result, in that year, the NKRAFA started a scheme that encouraged the air cadets to participate in a UAV competition, calling 'UAS Contest'. This competition has been annually subsidized by the RTAF. In 2014, the participants were mainly from Aeronautical Engineering and Mechanical Engineering Department because they were trained and educated in the UAV domain as mentioned earlier. By joining this UAV contest, the objectives and rules are shown as follows:
<u>Objectives</u>

1. Air Cadets had knowledge and experiences with components and subsystems of the unmanned aerial vehicles (UAVs)
2. Air Cadets were capable of flying UAVs autonomously
3. Air Cadets were capable of planning the flight according to the assigned mission
4. Air Cadets could do the parameters tuning of the flight controller to control the UAVs effectively

<u>Rules</u>
After Air Cadets finished the training to be able to take off and land the UAVs autonomously, the mission of the competition was the following.

1. Split the air cadets into 8 groups and each group consists of 10 cadets (2 cadets from each class)
2. Each group would have to search and identify the targets that were randomly placed on the football field.
3. Each group would receive the coordinate of 24 targets for flight planning. However, each group would need to search and identify only 3 targets that had the number of their group on that target.
4. Each group needed to specify the shape and color of the targets that had their group number on (see Figure 1).

5. Scores of the mission would be based on the correctness of the searched and identified targets and the amount of time spent on the whole mission.

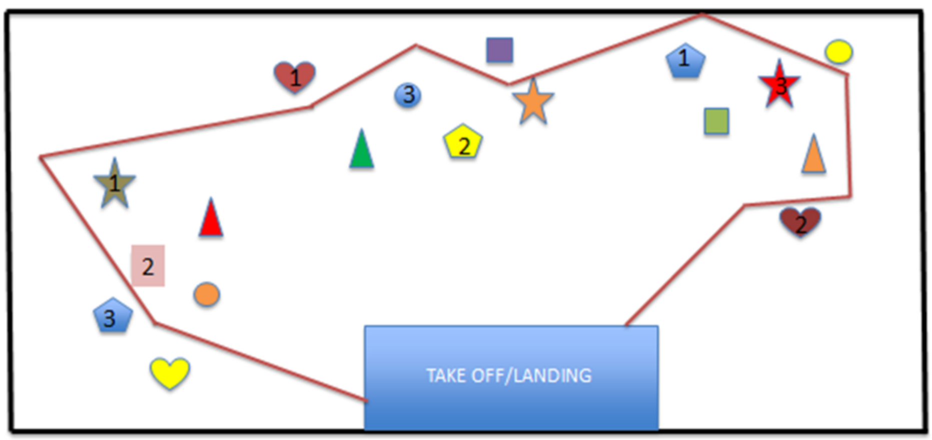

Figure 1. Example of the competition mission layout

Figure 2. Provided UAVs for the competition

Figure 3. Air Cadets' flight test during the competition

After hosting the competition for two consecutive years, post-match results were not relatively satisfactory. Although the air cadets from every department joined the race, the key players were still mainly from Aeronautical Engineering and Mechanical Engineering Department. The participants from other departments were mostly responsible for administrative tasks rather than operating the field missions. As a result, those who were not in the field test did not have any inspiration after the competition witnessed from the post-competition questionnaire. Other activities such as club establishment were also not found after the race. Furthermore, the UAV team members (air cadets and professors) that joined other competitions held by other universities were only from the two mentioned departments. The overall satisfaction in 2014 and 2015 are shown in Table 1. The overall rating is moderate. And there are some negative comments about time-consuming and not having a background understanding.

Table 1. Overall Satisfaction in the year of 2014 and 2015

Year	Number of Response	Overall Satisfaction	SD	Comments
2014	75	3.9	0.51	1. Time consuming 2. Not having background understanding 3. A bit boring
2015	69	3.7	0.49	1. Time consuming 2. Not having background understanding 3. Unrelated to the field of study

COMPETITION WITH CDIO CONCEPT

Due to unsatisfactory feedback from the previous competitions, the CDIO concept was introduced to the staff group. The idea was about providing air cadets the real-world situation of which the cadets have to find the solutions. The academy then decided to change the rules by focusing on the importance of using UAVs in military contents and Air Force missions. Before the race, the air cadets were lectured about UAVs and the instructions of aerial use. Then they acquired the concept of air operations and military doctrine in the next stage.

Procedures and Rules

The process began with the step of giving the air cadets lecture about aircraft design for 10 hours by using the Plane Maker aircraft design aid, which is part of the X-Plane 9 flight simulator. This made the air cadets able to design wing shape, body, tail ring set, ground control and also to simulate this aircraft by using the X-Plane 9 flight simulator. Then the instructor introduced the theoretical concept of flight control for 10 hours including relevant gauges in a flight control system such as speedometer, altimeter, GPS positioning system, and tilt gauge. Subsequently, the air cadets conducted practical studies using the AutoPilot flight control system to configure various connecting the flight control system to the aircraft's motor, wireless communication system, and Ground Control Station (GCS). Once completed, the unmanned flight system could be simulated using the AutoPilot Flight Control System in conjunction with the X-Plane 9 flight simulator to simulate the system and practice proficiency in flight control. Then, the cadets had an opportunity to install automatic flight control systems with the aircraft to test a flight for achieving the positions that were originally planned for the mission.

After instructing how to design and use UAVs, the basic air doctrines were introduced to air cadets. These included: 1. Strategic Attack: Destroy the strengths of the opponent, 2. Counter Air: Offensive Counter Air and Defensive Counter Air, 3. Counter Land: Dominate the enemy's ground environment, 4. Information Operation: Induction or protection of information, 5. Airlift: Transport of personnel and air ammunition, 6. Intelligence: Analyze, evaluate, and interpret news and data, 7. Surveillance and Reconnaissance: Systematic observation of the airspace, 8. Navigation and Positioning: Air Navigation and Coordinate Map, and 9. Military operations other than war: resolving conflict, promoting peace, and supporting civil authorities in response to domestic crises.

By using an air combat simulation model, air cadets were divided into two teams; the red team and the blue team. Each team would have four sub-groups: 1. Intelligence Surveillance and Reconnaissance (ISR Team) – responsible for linking all battlefield functions and information collected from air surveillance to assist a combat force in employing its troops, 2. Command and Control (C2) – responsible for directing all resources to achieve the goals, 3. Squadron (SQRN) – responsible for air attacking and bombing based on the C2 command, and 4. Special Forces (SF) – responsible for searching and rescuing the troops and civilians.

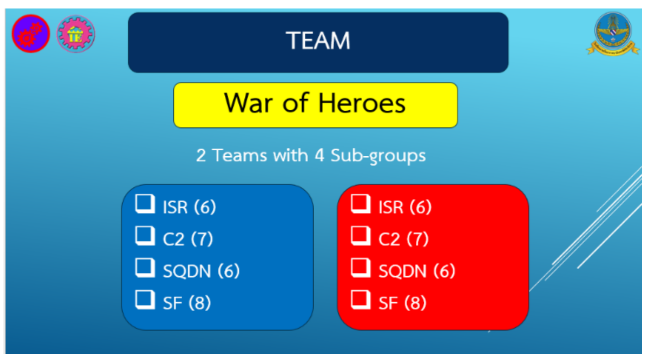

Figure 4. Team with four sub-groups

The scenario arose with the boundary conflict between the two countries. The leaders of the countries stated the negotiation. However, they could not make any commitment that led to the deployment of arm forces. The prime minister of each country approved the deployment of defensive forces and primarily focused on air and missile attack. The C2 team had 10 minutes to plan and establish an air operation and 10 minutes to plot all necessary places (airport, headquarter, school, etc.) on the grid provided. Then the ISR team began reconnaissance operation for the first round (2 minutes) with the flight ceiling that was high enough to avoid the sensor on the ground. The collected data was reported to the C2 team to adjust the flight planning. The ISR team then had another chance for reconnaissance operation. Afterward, the air attack operations were activated. When the team dropped the bombs (flour bags) into the strategic targets such as headquarter and airports, the 20 million Token (created currency) was transferred to that team. However, if the bombs dropped into civilian targets such as temples and schools, 20 million Token was withdrawn. And if the sensor could detect any flight, 10 million Token was withdrawn as well. At the end of the scenario, life bags were dropped to help alleviate the war effects. This stage was called military operations other than war.

Figure 5. Competition Environment

Consequences of the Competition

All air cadets were able to take part in all competition processes. Although some cadets did not have any background on using UAVs, they had choices of participating in Command and Control as well as other field-operated functions. This led them to understand the missions of the RTAF as well as the military doctrine. When they received the given problem, they were keen to run brainstorming as a team. The necessary information (i.e. avoidance ceiling for the ground sensor, resolution of the UAV camera, the weight of flour bag, and so on) were not given to them at first; therefore, they had to figure out themselves by going through series of trial and error. They took every minute as a treasure and eager to find the solution when they faced the problem. This cannot be seen in the usual class environment especially when the students are in the military. The overall satisfaction raised from below 4 to 4.47 (SD 0.63). Surprisingly, comments from the questionnaires were that the competition should have been longer. Furthermore, they requested more participants to join the competition as shown in Table 2.

Table 2. Overall Satisfaction in the year of 2015

Year	Number of Response	Overall Satisfaction	SD	Comments
2015	65	4.47	0.63	1. The competition should have been longer 2. More cadets should have participated 3. The rules should have been well organized to avoid confusion

After receiving good feedback in 2015, the competitions were conducted in 2016 and 2017 continually with the same rules. And overall satisfaction scores were both higher than 4.5. The number of air cadets joining the competition rose to 120 cadets in 2017. The rivalry lasted two days. The first day was for testing and rehearsal and the second day was the competition day. There was an increase in the number of cadets interested in UAVs and wanted to join other competitions held by other universities. This led to the establishment of the NKRAFA UAV Club in 2017.

The Impact of the competition

As mentioned before, the cadets interested in UAV who joined the competition outside the academy were all from Aeronautical and Mechanical Engineering Departments. After the club setting, the number of cadets from other departments has increased gradually. In 2017, the two teams from NKRAFA won the first and second prizes of Autonomous Aerial Vehicle Challenge 2017 (AAVC 2017). Additionally, the team members were from different departments and classes (freshmen, sophomore, and junior). The professors from other departments also joined as team members. This causes the attentiveness of UAVs in the academy. More cadets have joined the club and the number of professors taking part in such activities increased as well as the number of research regarding UAVs as shown in Table 3.

Table 3. Number of cadets, professors and researches relating to UAV

Year	Number of cadets in the club	Number of professors	Number of researches
2017	20	7	12
2018	24	10	12
2019	39	15	17

In 2018, cadets in the UAV club found that there was an international UAV competition called UAV Challenge 2018 held in Australia and they asked professors for permission to join this competition. It was a big surprise since it was a rare occasion that cadets asked to join the competition themselves. However, there was no budget at that time because it needed at least one year in advance to do paperwork. All professors in the academy were firstly asked for a donation, and later on, they received a special budget from the Commander in Chief of the Royal Thai Air Force to join this competition. They contacted the organizer of the event themselves. They also sent an email to the commercial firm to acquire information about the UAV parts shown in Figure 6 (note that the company name was censored). The team contained members from various departments (Aeronautical Eng., Mechanical Eng., Electrical Eng., Civil Eng., and Material Science Departments). They also had all classes (freshmen, sophomores, juniors, and seniors) on the team. Although they won the fourth rank out of 55 qualified teams, they were the only team that received the Airmanship award. This award was judged by the decision-making of the team members.

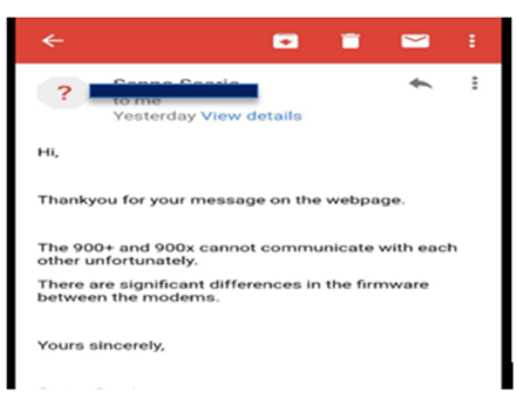

Figure 6. Email sent by cadets

CDIO STANDARDS

To teach cadets, the hardest thing is that they do not have any inspiration to learn because they already know their career path. Therefore, they do everything just enough to pass the criteria. Moreover, a military person will follow the order from his commander by nature that he is taught to be a follower. And cadets have a bit of this nature from military training and the environment (Jantarachotigul, 2020). However, the academy has the mission to produce commissioned air officers that will be leaders of the Air Force. One of the most vital skills for leaders is critical thinking. This contrast makes it challenging to teach cadets at the academy.

When we looked back to what happened, this practice seemed like the first step of CDIO Implementation. Traditionally, problems were given to air cadets with a platform for solving. They did it unintentionally in the same manner as the air cadets did in1960s. Soldiers passed their traditions from generation to generation with very little difference. This implementation can be the first step of behavioral change. The authors have taught air cadets in this academy for more than 10 and 16 years, and we have never seen this scenario before. This transition brings alertness to the academy. The air cadets have willing to study and find the solution themselves, which is the key to educating people.

The academy is now interested in the idea of implementing the CDIO concept by encouraging all departments to carry out the CDIO concept into a new curriculum submitted to the Ministry of Higher Education, Science, Research and Innovation by 2024. The academy has set up a series of problem-based learning workshops since 2018. Based on Self-Assessment of CDIO Compliance projected by CDIO Initiative (2014), this complies with Standard 1 - CDIO as Context. The chief commanders of the academy now understand the need of implementing the CDIO concept in the academy. They also have willing to create an internal environment in which everyone can take part in the program. Not only ones in the academy, but also alumni and stakeholders participate in the program. There are several meetings between the academy and the representatives from every directorate in the air force to evaluate the learning outcomes. The necessary results they need are problem-solving skills, interpersonal skills, and technological skills. They appreciated that cadets could produce microsatellite. This was after the competition and the establishment of the UAV club. Apart from designing and experimenting with UAVs, they expand their knowledge by gathering information about satellites, designing, and producing it by themselves. The academy now recognizes that multidisciplinary education is a need. Therefore, instead of studying military sciences, the new curriculum (2020) allows cadets to choose a group of elective courses to learn (for 15 credits) in three domains: Air Power, Space, and Cyber. These comply with Standard 2 - CDIO Syllabus Outcomes and Standard 3 - Integrated Curriculum.

Beyond the first three standards, the competition is the first step that inspires cadets to think systematically and logically and act intentionally. It relates to the fifth standard of CDIO - Design-Implement Experiences. When cadets conceived the problem, they developed their strategies based on previous knowledge and brainstorming. They have to integrate all technical information and military procedures. After designing, they have to test whether it works in a given situation. We have increased the complexity of the rules every year. Although the rules for 2015-2017 were the same, the detail of objects was different such as the side of the target got smaller. In 2018, the rule for the competition was revised based on the rules that the team encountered when they joined the international competition. These included UAV use in medical function and evacuation.

To accomplish the competition goal, space for cadets to work and test their UAVs is a must. After the first year of the competition, the academy set up the laboratory called CDIO Room for Aviation and Space Technology (as shown in Figure 7) that opens 24 hours, and all cadets can use this room to discuss and exchange their knowledge with others. The activities that occurred in this room are not limited to the projects relating to UAVs. It is student-centered, user-friendly, accessible, and interactive. This creation of new workspaces conforms to the sixth standard - CDIO Workspaces.

Figure 7. CDIO Room

CONCLUSION

UAVs have been received more attention for both private operations and military missions. The NKRAFA encouraged air cadets to learn the UAV concept not only in-class lectures but in field competitions. Thus, the air cadets would receive more understandings of UAV operations via assigned missions. The competition, however, did not convince the air cadets to show their problem-solving ability resulting in unsatisfied performance. The NKRAFA, therefore, has employed the CDIO concept for applying the UAV learning technique, with the hope that the air cadets would able to improve problem-solving performance. By implementing the CDIO concept in UAV competitions, the air cadets have satisfactory results as expected. Therefore, this excellent educational framework is certainly suitable for implementing along with the curriculum in order that the air cadets are able to deal with problem-solving circumstances more efficiently and effectively. The principle of CDIO would be more vital for educating implementation in the future particularly in UAV mission training, which is one of the key policies of the RTAF.

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A CDIO COMPETENCY FRAMEWORK FOR VINH UNIVERSITY'S TEACHING FACULTY

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ABSTRACT

Among factors that a university can control, teaching faculty plays the most crucial role (Hammond, Berry & Thoreson, 2010). This may explain why professional teachers at higher education institutes are generally required to possess essential competencies for the benefits of students. While many educators have agreed on the distinctive nature of higher education as compared to K12 levels, there seems to be no consensus on what competencies are the most fundamental. This paper in the first place argues for the necessity to formulate a lecturer competency framework for the teaching faculty at Vinh University, which has recently launched its newly designed CDIO curricula. The university has undergone a significant transformation since it joined the CDIO Initiative in 2005, thus being determined to reset its policy on requisite attributes for the lecturers. The paper also discusses the elements of competency, advantages of lecturer competency frameworks, and principles of formulating lecturer competency frameworks. In addition to that, reviews of teacher competency frameworks currently used by schools and universities around the world are provided. Finally, the paper describes the components included in the proposed framework together with explanations for the inclusion of those competencies.

KEYWORDS

faculty competence, teaching competence, CDIO competencies, CDIO competency framework, Standards: 9, 10

INTRODUCTION

Teacher competence is an essential factor in the education process (Tanguihan, 2016). A teacher has to perform various roles and thus is required to own specific skills, knowledge and attitudes in order to facilitate student learning. Previous studies have shown that of all the factors that a school can control, teaching faculty has the most significant impact on learner success (Sanders & Rivers, 1996; Izumi & Evers, 2002; Babu & Mendro, 2003; Leong, Singh & Sale, 2016). Several scholars assert that teachers who own standardized teaching certifications and attend professional training courses more frequently tend to produce better learning results (Hammond, Berry & Thoreson, 2010). Along similar lines, Gee (2018) found a positive correlation between teacher competence and student satisfaction.

An educational institution may require its teaching faculty to have certain qualifications and competencies depending on the economic, social and political context as well as its educational needs. Although requirements may vary, they should be formulated in such a way that they would contribute to the teacher development process and facilitate the building of a strong and high-quality teaching community. Ministries of education in different countries have developed *national teacher competency frameworks*, which are commonly used as a compass to direct teachers' professional development and to assist them in their job performance.

Since it joined the CDIO Initiative, Vinh University has faced new challenges in innovating curricula and teaching methods. The implementation of the newly designed CDIO-based curricula has urged our lecturers to develop their personal and interpersonal skills, product, process, and system building skills as well as instructional skills (Đinh, Thái & Nguyễn, 2016). Although the university has issued *institutional personnel regulation* that points out several requirements for the lecturers, those statements are too generic and thus can barely be used to assist any stakeholders. A lecturer competency framework should, therefore, be established in order to provide the teaching faculty with a guideline for professional development throughout their careers. This type of document would also offer the administrators a useful reference for the process of recruiting, training, and evaluating the university's personnel.

LITERATURE REVIEW

Teacher Competence

The term *teacher competence* has been defined by various scholars. According to the European Commission (2003), teacher competence is a *"complex combination of knowledge, skills, understanding, values and attitudes, leading to effective action in situation"*. For Houston (1985), teacher competence means skills and knowledge that a student must demonstrate upon completion of a teacher education program. Other researchers believe that teacher competence refers to skills and knowledge that teachers need in order to be successful in their career (Jackson, 1990; Spencer & Spencer, 1993; Boulter et al., 2003). This concept has also been defined as the combination of knowledge, skills and behaviors used for improving teaching quality or for performing an educational task (Tompea, 2011).

Past research has identified specific competencies that a teacher needs to gain in order to be qualified, including intellectual ability (Krauss et al., 2008), management skills, interpersonal skills (Hong et al., 2008; EU), proper contact with the audience (Huntley, 2003), problem solving skills and assessment methods (Peklaj, 2015), research and reflection skills (European Commission, 2013), critical thinking (Mac Laughlin & Talbert, 2001), the ability to create new knowledge (Cochran-Smith & Lytle, 2009) and the ability to adapt the curriculum to meet the learner's needs (Hatano & Oura, 2003, Vogt & Rogalla, 2009). In this study, we define teacher competence as the combination of knowledge, skills and attitudes to successfully perform teaching tasks in the contemporary educational context.

Developing a Framework of Teacher Competences

Teacher competency frameworks are valuable to almost all stakeholders of an educational system. The list of teacher competencies allows the stakeholders to be assured that all teachers have attained minimum standards and might serve as the basis for institutional or national recognition of the quality of teaching. The parameters in those frameworks can be of great use in recruitment, human management, evaluation and training processes. Without this set of teacher standards, these processes may be intuitive and inconsistent.

A few educators have attempted to formulate teacher competency frameworks. Selvi (2007), for instance, proposes that a teacher competency framework should comprise such components as technical competence, research competence, curriculum design and development competence, technology competence, communication competence and environment competence. More recently, Wing Institute (2020) has reported that the four most agreed aspects of teacher competency are teaching competence, classroom management competence, formative assessment competence, and interpersonal competence. However, Peklaj (2015) advocates a three-dimension framework that organizes teacher competencies into three groups: teacher competencies for promoting cognitive processes, teacher competencies for promoting affective-motivational processes, and teacher competencies for promoting social processes in students. Along similar lines, Vijay (2013)'s framework consists of three categories of competencies (teaching competence, organization competence and assessment competence).

Previous studies have discussed key features of a teacher competency framework. The European Commission (2013) contend that such parameters should be grounded in the culture of the country; be based upon a negotiated consensus about the purpose of teaching and about what constitutes successful teaching and learning; be based on the university's educational philosophy; accommodate all the dimensions of teachers' professional work, in an integrated way; be based on the understanding that teaching involves a cycle of self-evaluation and improvement; be consistent with (but not limited by) the desired learner outcomes (e.g. in national curriculum guidelines); and have the key attributes of stability, durability and flexibility. Likewise, the Australian Ministerial Council on Education, Employment Training and Youth Affairs (2003) lists eight principles for developing a national teacher competency framework as follows: acknowledge the link between quality teaching and improved student learning outcomes; ensure consistency and enable recognition of quality teaching; reflect authentic and extensive knowledge about teaching and learning; encourage teachers to aspire to a higher level of performance; have regard for the future but are grounded in current effective professional practice; reflect the theoretical knowledge of specific content and pedagogy and the practical application of that knowledge to improve student learning; are outcomes–based to ensure strong links between standards for teaching, their evaluation and professional learning; reflect teachers' professional experience and growth on a continuum from undergraduate preparation to professional leadership; and, promote, support, recognise and reward quality teaching in the full range of social and cultural contexts in which teaching occurs.

Teacher Competency Frameworks around the World

Many countries have declared their ways of defining teacher competences through either a simple linear or a multi-dimensional framework. These approaches to teacher competency framework development range from a light touch description such as government decrees on university qualifications (Finland), guidelines for broad outcomes expected of a teacher education curricula (Croatia), legislation describing teacher competences and skills that teacher education curricula must meet (Denmark) to complex description such as detailed lists of competences broken down into skills, knowledge, attitudes or values, together with indicators or can-do statements (Netherlands, Belgium, Scotland). Many of these frameworks are distinguished by school level and expertise level too (Australia, New Zealand)

A scrutiny into competency frameworks used in different countries has shown that although many countries have a national competency framework for K12 teachers. For example, the Western Australia's framework outlines competency standards for effective teaching across three broad phases of teacher's work and is based on a construct of five dimensions of teaching (facilitating student learning, assessing and reporting student learning outcomes, engaging professional learning, participating in curriculum policy and other program initiatives in an outcomes-focused environment, forming partnerships with the school community). The Southeast Asia Teachers Competency Framework (The 11 Southeast Asia countries, 2018), which was endorsed by the SEAMEO High Officials Meeting in 2017 and later adopted by the Council of Ministers of Education from 11 countries in the region, consists of four essential competencies (knowing and understanding what to teach, helping students learn, engaging the community, and becoming a better teacher everyday) and twelve general competencies teachers must possess.

The currently available competency frameworks for university lecturers, however, are institutional rather than national. These frameworks were developed by universities to be used by their own stakeholders and thus merely share a common structure. For Vrije University of Amsterdam, the teaching faculty of this university is expected to possess five core competencies, namely didactic flexibility, social flexibility, developing teaching, cooperation and conscious lectureship. Meanwhile, Algonquin College (2013) established a competency framework for professors of the 21st century across three expertise levels (0-2 years' teaching, 2-7 years' teaching and 7+ years' teaching). As per this set of standards, a professor should attain seven competences (modeling professional practice within the discipline of teaching, creating engaging learning environments for individuals and groups that support academic and personal growth, using a variety of teaching/learning strategies, evaluating learning using a variety of valid and reliable tools and techniques, working independently and with others to develop and/or adapt learning materials, using technology to enhance productivity and helps students learn, designing and developing effective curriculum to support student success).

CDIO LECTURER COMPETENCE

The CDIO Standards 9 and 10 emphasize the importance of enhancing lecturer competence in personal and interpersonal skills, product, process and system building skills, providing integrated learning experiences, using active and experiential learning methods and assessing student learning. In the light of these standards, CDIO advocates have confirmed the necessity for lecturers to possess these competencies. For instance, Malmqvist, Gunnarsson and Eigild (2008) propose a list of situations in which CDIO lecturers have to possess professional skills so as to help students obtain those skills. The researchers found that the faculties members in their study agreed that proficiency in professional skills, and the skills to teach project-based courses and relate their research to the industrial context are essential for their work. Along similar lines, Crawley (2014) asserts that since lecturers have to teach personal and interpersonal skills, product, process and system building skills, they should be assisted to obtain those skills.

Although the importance of CDIO skills for lecturers has been emphasized, research in developing frameworks for CDIO lecturer competency is still in its infancy. Among the published works related to this topic, Leong, Singh and Sale (2016)'s is probably one of the most influential studies. These authors mentioned the Lecturer Competency Framework developed by 5 Singapore Polytechnics and the professional development programs in Singapore Polytechnic. The framework contains 11 subsumed competencies grouped into 6 domains of competencies, namely curriculum design and development, facilitation of learning, assessment for and of learning, holistic student development, dual professionals and reflective practitioners.

OUR CONTEXT

In Vietnam, studies have shown that the CDIO approach can be applied to non-engineering disciplines given that a general description of CDIO is applied, a professional context of the education can be identified, and that the CDIO standards are translated to the context in question (Đoàn & Nguyễn, 2013; Lê, 2019). There is a growing body of literature on how universities in Vietnam adopted the framework for their educational programs (Phạm, 2016; Phạm, 2017).

Vinh University has unceasingly endeavored to improve its offerings, the most obvious manifestation of which is its continuous innovation in curriculum development and teaching quality assurance. The university's most recent educational revolution embarked in 2016, when the CDIO framework was selected to be the underpinning for the curriculum design of all the programs, including the non-engineering ones. During the period from 2016 to 2018, the then existing programs were redesigned. At that time, our main working team members had almost no previous experience with curriculum design, nor were they familiarized with contemporary educational trends. In order to overcome this obstacle, the university sent members from both academic and administrative departments to visit leading CDIO innovative universities while workshops for faculty by well-known experts in the field of curriculum design and CDIO framework were organized on campus. This was unfortunately a slow and laborious, but ultimately very rewarding process. The new curricula were yielded after two years and launched in September 2018. After four years of experimenting, struggling and learning, we have found that CDIO framework is probably the one-type-fits-all approach to designing the university educational programs.

One of the major challenges the university has had to face is overcoming faculty resistance to teaching skills outside of their subject specialty. This is perhaps due to the deep-rooted traditional view of lecturers as purely knowledge presenters rather than learning facilitators. In order to successfully execute the CDIO-based programs, the lecturers have to attain new competencies, including personal and interpersonal skills as well as product, process and system building skills. The changing society at the same time requires them to design and adapt the curricula periodically, which in turns, demands them to possess competencies in curriculum design and development. However, back in 2016, most of the staff members had rather little knowledge of these fields. Many of them were puzzled not knowing what they would have to obtain in order to effectively implement the CDIO programs. The fact that administrators were not sure who among the staff needed how much training in what areas worsened the problem. These obstacles would be overcome if there existed a lecturer competency framework that allows stakeholders to be sure what is needed for a lecturer to accomplish their mission. For this reason, the university management board requested the most prestigious experts to come together and develop a framework for lecturer competences.

THE PROJECT

The project commenced in March 2019. First, a group of experts met to determine the principles that would govern the framework development process. First, the framework has to be grounded in the university's cultural and educational context. Our first and foremost contextual consideration is that most of our teaching faculty, although had gained some knowledge about CDIO, were not competent in designing and implementing a CDIO program. Many of the lecturers had no degree or previous training in teaching methodology and thus were not familiar with such concepts as active learning, integrated learning, and experiential learning. Another contextual consideration we had to keep in mind is that the university has been striving to be included in the Asia University Rankings, which uses research as one of the judgment criteria. This means the teaching faculty should be encouraged to improve their research competence. Therefore, this domain would have to be included in the framework.

The second principle for developing the framework concerns the purposes it will be used for. Apparently the framework has to be developed in such a way that it can serve the process of professional development and teacher quality assurance. Moreover, it should be used for attracting competent teachers, managing but not hindering staff promotion or limiting professional agency. The lecturer standards have to be described in a transparent manner so that all relevant stakeholders can understand and make use of it. Finally, the framework should not be something permanent and rigid but adaptable and flexible to fit the changing societal, political and cultural context.

The expert team also agreed on the grounds upon which the framework would be developed. These bases include the global, regional and national context; the educational culture of the country and the University; the characteristics of higher education; the teaching faculty's current competence; and theories on teacher competence and frameworks for teacher competences. The Vietnam Education Law and the national standards for lecturers were taken into consideration too. It is required by the Ministry of Education that lecturers have to meet the following criteria: have good morality, dignity and political stance; own a bachelor degree and a certificate of teaching methodology; be competent in a foreign language and computer skills; be healthy; have a transparent citizen record.

Additionally, the team took a careful examination into the University's vision, missions and goals. The University envisions becoming a national key university and a member of the ASEAN’s University Network. Its mission is to provide high quality human resources for society through the pursuit of education and training at the national level of excellence; to deliver teacher training and continuing professional development; and to function as a leading center for educational, applied and basic research and technological transfer in the Northern Central Vietnam as well as nationwide. The University's goal is to create a good academic environment to develop students’ competencies and personal attributes that lead towards their success. In order for the University to realize the vision, fulfill the missions and reach the goals, the teaching faculty has to obtain certain competencies.

The team also used the University's regulations as a basis for determining a list of competencies that the lecturers should possess. According to the University's regulations, lecturers have to comply with the Law, the government's policies, and other national and local regulations; fulfill all professional duties such as teaching, doing research, designing curricula, instruct students to do research and other types of tasks assigned by the administrators. Finally, the University's Strategic Development Plan for the years 2018-2020 and vision for 2030 were taken into consideration. In this plan, a list of strategies are grouped into different domains such as training program, research and innovation, external collaboration, educational environment and resources, teaching and learning support. We were fully aware that the framework must contain competency elements that would help the University to execute its strategic development plan.

THE FRAMEWORK

The draft of CDIO lecturer competency framework was sent to all relevant units and cells within the University around October 2019. Modification was made based on the feedback results before another version was sent out again. This procedure repeated and it was not until a year later that the final draft was presented in front of all key lecturers and administrators. The final version of our CDIO lecturer competency framework comprises seven domains of competencies together with the suggested evidence for each domain. Table 1 illustrates the rationale for choosing each domain.

Table 1. Domains of the CDIO lecturer competency framework

Domain of competency	Rationale/Basis
Work ethics (Morality and political stance)	- This is to meet the lecturer standards regulated by the Vietnamese government.
Field (competencies regarding the subjects lecturers teach)	- Field competencies are a prerequisite for the teaching profession. - This domain would help the University to accomplish its mission to produce high quality human resources.
Pedagogy (competencies involved in making pedagogical choices throughout the process of teaching)	- Pedagogical competencies play an influential role in the teacher profession. The University's vision is to become a national key university and a member of the ASEAN's University Network. In order to realize this vision, the teaching faculty has to do their teaching job effectively. Competencies in pedagogy enhance the lecturer's teaching quality. - This allows the University to reach the second objectives stated in the strategic development plan (the University will gradually increase the number of high quality programs), to fulfill its mission of building a high quality academic environment for learners to develop personal and professional attributes necessary for success.
Foreign language and information - technologies (competencies of a foreign language and information-technologies)	- Competencies of a foreign language and information-technologies allow lecturers to effectively implement the curricula, carry out research and promote international relationships. - This domain of competency also facilitates the development of competencies in other domains, such as research, communication with the industries and international collaboration.
Research (competencies of research methods and techniques, designing and carrying out research)	- Competencies to design and carry out research are fundamental in higher education. - This domain of competency is said to affect the development of other domains of competencies. - This group of competencies are necessary for the University to realize its vision of becoming a member of the ASEAN's University Network and its mission to function as a leading center for educational, applied and basic research and technological transfer
CDIO curriculum (CDIO curriculum development competencies and CDIO curriculum implementation competencies)	- Competencies in CDIO curriculum development and implementation are essential as the University has joined the CDIO Initiative and started to implement the newly designed CDIO curricula for all the programs. - This domain of competency assists the lecturers in providing constantly improved teaching quality to the learners. - These competencies are necessary to accomplish its educational goals and strategic development plan (All the programs are periodically adapted and improved).

Domain of competency	Rationale/Basis
Communication with the industries (competencies of interacting with the industries and other stakeholders)	- In order to implement the CDIO curricula effectively, lecturers have to be competent in communicating with the industries. They should be able to collaborate with other stakeholders to create chances for students to practice skills (Malmqvist, Gunnarsson và Eigild, 2008). - A good partnership and relationship with the industries assists lecturers in designing the content and selecting appropriate assessment methods, and instructional techniques for the courses they deliver. - This is in agreement with the University's educational philosophy (collaboration). - This domain of competencies is also important for the third and six objectives in the strategic development plan to be reached (to enhance partnership with enterprises and employers to connect the education process with the industries, to tighten the relationships with enterprises and international associations to extend the network of internship, labor exportation and job orientation for learners).

Table 2 presents the domains of competency and components of each domain, together with the evidence for each component. The provision of evidence allows the competencies to be recognizable hence offers the administrators a basis for staff recruitment, management and evaluation. This will also provide the lecturers with a tool to determine and prioritize their professional growth.

Table 2. CDIO Lecturer Competency Framework for Vinh University's teaching faculty

Domain of competency	Component	Evidence
Work ethics	Political stance	- Annual staff evaluation sheet - Feedback from managers and colleagues
	Teacher conducts	- Professional training certificate - Feedback from managers, colleagues and students
Field	Knowledge	Master degree in the field
	Skills	Relevant degrees or certificates of training
Pedagogy	Planning the course	Course plans
	Designing and developing materials	Coursebooks, lesson plans, books
	Using teaching methods and techniques	- Diplomas in teaching methodology - Certificates of participation in pedagogical training workshops
	Assessing student learning	Certificates of participation in training workshops on assessment.
	Building the learning environment	- Feedback from learners - Evaluation from administrators
Foreign language and information - technologies	Using a foreign language and information-technologies in teaching, research and communication	- Certificate in information-technology as required by the Ministry and the University - Products showing competence in a foreign language and information - technologies (e.g. articles written in English, E-learning lesson plans, etc.)
Research	Designing and carrying out research and technological transfer	Research products
	Instructing learners to carry out research	Research products by the learners
CDIO curriculum	Designing CDIO curricula	CDIO-based course syllabi that have been designed and implemented
	Implementing and developing CDIO curricula	Improved CDIO-based course syllabi
Communication with the industries	- Setting up the network of enterprises and/or associations - Communicating with partners	- An established network of enterprises and/or associations - Results from partnership with enterprises and/or associations

CONCLUSION

The CDIO lecturer competency framework for Vinh University's was developed based on a relevant theories and grounds concerning competence, teacher competency, competency frameworks and CDIO lecturer competencies. Considerations of the economic, political and cultural context, the Vietnamese government's and the University's regulations were also made. The selection of the competencies was done with careful reference to the University's vision, mission, goals and strategic development plan for the period of 2020-2035. The framework, however, is not supposed to be something permanent and rigid. Since it was developed in regard to the social, cultural and political context, it may be adapted if future contextual changes require lecturers to possess new competencies.

The framework will offer several benefits to the stakeholders. First, it will provide a coherent approach to planned professional learning to improve teaching quality and a reliable basis for the University's budget allocation for lecturer quality priorities. Second, as it describes the competencies and evidence for competencies, the administrators can rely on it for staff evaluation and staff quality development planning. Apart from that, it establishes a common understanding of what the lecturers need to obtain to improve student learning and realize the University's vision. This will in turns encourage them to aspire to a higher level of performance.

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THE WIN-WIN OF SYNCHRONIZING LAST SEMESTER'S COMPUTER ENGINEERING COURSES

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ABSTRACT

This contribution addresses how two parallel courses during the last semester have been synchronized, where one is a course for Degree project. This is to give students a greater chance to complete the courses on time, and at the same time create a greater understanding of complicated problems. Observations have previously been made where students found it hard to take in, and finish the last semester's courses, at the same time as they complete their studies through their Degree project. Extensive revisions have been made to the parallel courses, where both basic course structures and contents have been taken into account. Clear improvements have been seen, both through course results, and based on students' comments.

KEYWORDS

Project-based education, Degree project/Thesis work, Computer Science and Engineering studies, IoT projects, Embedded systems, Standards: 2, 3, 5, 6, 7, 8

INTRODUCTION

The three-year Computer Science and Engineering program at Kristianstad University (HKR), Sweden, has for several years suffered from difficulties during the second semester of the third year, where students most often tend to miss significant deadlines. This semester, which is the students' last, comprises a final Degree project of 15 credits (HEC), which corresponds to half the work effort during the semester. Different approaches have been tested to give students the best possible conditions to complete the Degree project on time. On the one hand, the Degree project has been full-time during the latter part of the semester, with the first half consisting of other courses. On the other hand, the Degree project has run in parallel with other courses throughout the semester. However, both approaches have resulted in situations where the students in many cases do not complete the Degree project, and that other courses during the semester have also suffered.

A main revision of the Computer Science and Engineering program was made three years ago. The difficulties with the last semester have then also been considered. An effort has been made to develop synchronization opportunities between the courses during this semester. A big project course of 15 credits (HEC), Systems Engineering, that previously was run at the beginning of the semester, has been moved and improved so the content of the course, as well as levels of learning objectives and examination forms have been considered to suit the parallel ongoing course for the Degree project (Thesis). Students have been offered opportunities to develop and analyze advanced systems where the course Systems Engineering has been based on development and the implementation of embedded systems, while the course for Degree projects has been based on more theoretical and exploratory perspectives.

In the Systems Engineering course, the students design the systems with both hardware and software. At the same time, in Thesis course, they conduct literature studies, and investigate suitable analysis methods. Examples of projects include:
- Drones. Processors for these, as well as software to give these flying properties, are developed. Technical measurements are made, for analysis and evaluations. Measurements made are based, e.g., on the placement of sensors, and performance on technical protocols.
- Body Sensor Networks. Here, too, both hardware and software are designed to put the system into operation, and technical measurements are made to study at the usability of the system.

Synchronizing the courses has generally given good results, where the opportunity to complete the courses has increased drastically. A survey of the students' experiences has been made, and this has shown high satisfaction.

The program is clearly CDIO-oriented, which is also expressed in the programme curriculum (TBIT2, 2020). The perception is that the synchronization of courses described in this contribution, and the effects of this, further increase the fundamental values pointed out by the CDIO.

BACKGROUND

The Bachelor Programme of Computer Science and Engineering at Kristianstad University, Sweden, is three years programme and is provided for both national (Swedish) and international students. The program has existed since 2009 and has undergone three major changes in recent years. In 2013, the program underwent an extensive restructuring that led to a clearer focus on Embedded Systems. In 2017, further changes were made to the program, with a clear progression between the courses as well as a progression in academic skills. The focus has been changed to Internet of Things (IoT). New courses were introduced to strengthen progressions in projects, mathematics, physics, programming, computer science and computer technology as well as the main specialization in IoT. In the last revision, that was introduced in 2020, a new course has been added, "Research methodology in computer science" to ensure research connection and raise students' scientific attitudes as well as prepare students for the Degree project (see Figure 1).

The Computer Science department has been a member of the CDIO initiative since 2014 and the program is organized according to the principles of the CDIO initiative. Connections to the industry are achieved in the program through Work-based education and "design-build-test" - projects integrated in the subject courses. The learning objectives that are described in CDIO syllabus, are divided into 4 sections: 1) knowledge in the discipline, 2) personal and professional skills, 3) teamwork and communication, and 4) Conceive, Design, Implement, Operate.

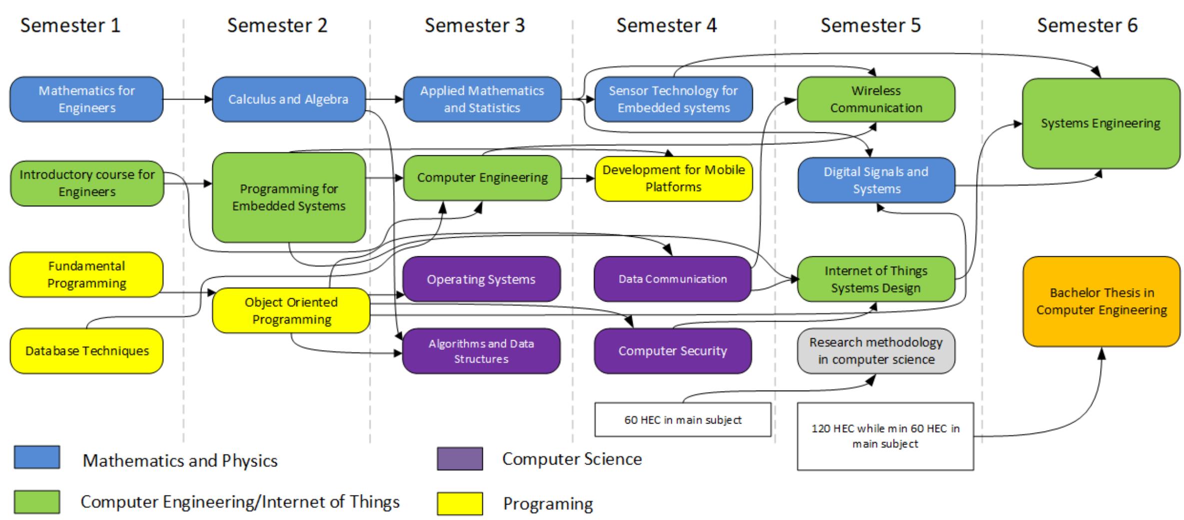

Figure 1: Bachelor Program in Computer Science and Engineering, HKR, (TBIT2, 2020).

Systems Engineering Course

The Systems Engineering course has been a part of the programme curriculum for more than ten years. During the live span of this course the main purpose of the course has always been to give the students a hands-on experience of prototype development of a system comprising of both hardware and software development. The project model used in the course has evolved from an iterative project model to an agile model over the years, with a formative assessment. Before 2013/14 the course was running as a fulltime course during the first part of the last, sixth, semester. From 2014/15 the course was running as a half-time course, for 20 weeks.

The course is organized in accordance with the principles of the CDIO initiative. The learning outcomes are related to the four sections of the CDIO syllabus (DT336B, 2020).

The Systems Engineering course is the second and last project course within the curriculum. The first project course, Computer Engineering, is held during the second year. The formative assessment is similar to the Systems Engineering course, limited in implementation. The prototype development project involves both hardware and software aspects as the Systems Engineering course. The scope of the project is small and introductory. Both hardware and software development are present, as well as agile project managing model, but in an introductory level.

Bachelor Thesis /Degree Project/ in Computer Engineering Course

The aim of the course is for the student to develop in-depth skills with independently planning, realizing and presenting an in-depth project within a defined area in computer engineering and technology. After completing the course, the student must:

- be able to explain and show understanding of matters within the field of computer engineering, including its scientific basis and applicable methods, along with an in-depth study of some selected part, plus have knowledge of current research issues (1)
  - be able to explain their knowledge in computer engineering and technology, as well as relevant knowledge in mathematics and science at an in-depth level (2) (DT339B, 2020).

Degree project was previously running as a separate course at the end of the education, as a full-time course for 10 weeks. From 2014/15 the course was running as a half-time course, for 20 weeks, last semester.

An idea to join the last two courses came in 2017/18 with a new course coordinator of the Degree project course. The course coordinators discussed the idea with the students one month before the courses´ starts. The response was clearly positive. Most of the students chose to join both courses. As a result, 7 of 10 students passed both courses on time. Those 3 students that did not pass on time, explained that their projects were too ambitious, and they needed more time to do more experiments and measurements. These students passed their theses one year after with very good grades.

During the latest revision (2019/20), the grading was updated with a clear assessment of all learning objectives. The students receive one grade for all parts, i.e., written report, oral presentation and written and oral opposition. This facilitates work for assessing teachers and course coordinator who reports the grades in the system.

RELATED WORK

It is important to see that educational programs should contribute to a scientific basis, as well as a high degree of employability for students. An integration of these two perspectives was addressed in Einarson & Lundblad (2014) where an industry-related project is seen as a case study of a scientific area being studied. This integration is carried out within the frames of a degree project of 15 credits, while the integration of two separate courses of 15 credits, as mentioned in this article, implies greater challenges, as well as greater values, with respect to, scientific basis and employability.

In most universities the Degree project course comprises 15 credits. Some universities provide separate course in research methodology just before the Degree project as well as separate project courses, also before the Degree project. For our knowledge, we did not find any university in Sweden, that combine the project and Degree project courses in computer engineering in one. There is one university (Umeå University, 2020) that combine the project course (laboratory) with a Degree project in molecular biology.

In Hakkala & Virtanen (2019) the authors present the structure model and visual tool for systematic thesis planning for engineering Master students at Turku University, Finland. The main concept is to efficiently bring the topic area of the thesis into focus while at the same time improving the readability, coherence and overall impact of a thesis. Teachers from Mongolian University of Science and Technology (Batdorj, Purevsuren, Purevdorj, & Gonchigsumlaa, 2018) present their experiences on teaching and learning activities as well as the assessment results of four project courses taught during the 3 years period. The program is based on CDIO syllabus and the Degree project is the last project in this progression line.

There are as well other aspects like quality of the Degree thesis. O. Svärd (Svärd, 2014) focuses on the concept of quality of the Degree project. He posts an interesting question whether an assessment of the quality of a Degree project can be used for evaluating the quality of the entire programme where it forms a part. The subject is partly initiated by the design of the quality evaluation system in Sweden introduced in 2011. In Sweden, engineering education is discussed, among other things, in the Swedish Engineers Group, represented by representatives from all engineering educations in Sweden. Ten of them offer bachelor engineering education in computer science, while some of them are based on CDIO syllabus.

IMPLEMENTATION

Both courses begin during the spring semester in January. The courses´ coordinators meet with students about 2-3 months earlier. During the information meeting, opportunities and difficulties are presented as well as reflections and recommendations (see Table 1) from previous year's students. The message about joining the courses is:

- Work on the same idea
- Design and build a prototype software and the hardware system in the Systems Engineering course
- Use the prototype system for research and evaluation in the Degree project course.

However, both courses are treated separately with different learning outcomes. The students are even informed that they are graded in two different ways. It is worth to mention that Systems Engineering course is the last project course in project-progression line while Degree project is the last one in an academic skills progression.

Table 1: Recommendations and reflections from students

“Both courses are time consuming, it is important that you do not just work on one part and forget the other. I can imagine that it is easy for the Systems Engineering course to become a major focus in the beginning - but that the Thesis is a bit on the side. But we were careful to work on everything theoretical, literature study, all writing and a clear picture of the appearance of the Thesis itself, even though we worked towards a fully functioning system in the Systems Engineering course.”
“This is tricky. It didn’t feel like that when we realized that we wouldn’t finish the Degree project in time but now that everything is said and done and we finished and passed both courses I think it was a good idea.”
“In order to manage both courses, it is good to consider both projects as separate, because the Systems Engineering took more time to get approved and start working. This will delay the thesis.”
“Communication with your partners. Set up priority due to the different timeline. Try to finish everything ASAP, instead of postponing it. We have a strong motivation to finish everything, my partner need to pursue further study(master) and I need to start working in June, so we have no choice (sadly □). That's the driven power for us to try to finish everything. It was a bit hard due to the COVID-19situation and also high volume, but both the teachers from the university and the company are really helpful and understanding.”

Systems Engineering Implementation

The teaching in this course consists of lectures, laboratory exercises and mandatory project meetings, and furthermore help sessions (informal project meetings). The course has two parts, where part one consists of lectures and laboratory exercises. The purpose of part one is to give the students practical experience of hardware design and manufacturing together with a lecture series in project management.

The second part consists of mandatory project meetings and help sessions (informal project meetings). The mandatory project meetings evenly distributed over the whole semester. The seven project meetings are assessed in connection with the meetings themselves, thus giving the student instant feedback of their progress in the project. This is the main procedure for the formative examination which is a part of this course.

The course consists of three examinations, hardware development, software development and project management. The students can by themselves decide which grade they are aiming for, regarding the hardware and software development examination. Together with the examining teacher, the student group decide the hardware and software requirements for the project. The grade is predetermined depending on the extent of the requirements. Thus, the students are well aware from the beginning of the course how to archive the different grades.
The project management assessment is done continuously during the course run in conjunction with the mandatory project meetings, i.e., this assessment is not predetermined (if the agreed requirements are fulfilled) as the other two, instead it assesses the whole project cycle.

The students conduct tin soldering, design, and prototype manufacturing of printed circuit boards during the hardware development part of the course. The Software development part incorporates software for several separate embedded units, where the units communicate wirelessly. These both parts include design, implementation, test and integration of software modules and hardware modules. The project management part embodies agile project planning during the course, written documentation, and a final presentation of the project.

Degree Project Implementation

The course is conducted in the form of an independent project (Bachelor thesis / Degree project). The work takes place in pairs of two students, unless there are special reasons for doing otherwise. This includes independently planning, conducting, and reporting back an empirical research study both in writing and orally. In connection with the Degree thesis project, the students receive an academic supervision. The students must define the task in writing at an early stage, conduct an analysis of the hypothesis or problem description and produce a schedule in collaboration with the academic supervisor. The students have also a possibility to choose to do the thesis at a company. In that case the students have also an external supervisor. Each Degree project is assigned also an examiner at HKR.

The course coordinator coordinates the course with all involved persons: students, supervisors, external supervisors and examiners to allow the Degree projects being carried out successfully. The responsibilities of the course coordinator include informing students about the policy and guidelines for the Degree projects, where they can find information about the course, as well as organizing and implementing the activities of the course (submission deadlines for project ideas, project plans, mid-way seminar and final presentation). The course coordinator acts also as a supervisor and examinator. The main challenge for the course coordinator is a communication between all partners, i.e., students and teachers. The course coordinator discusses each project plan as well as each thesis with both the supervisor and the examiner.

The course material consists of a document called *Study guide*, where students find all important dates (deadlines), description of all roles (and responsibilities), explanation of course´s contents as well as guidelines to written report, presentation and opposition. To help students, the course page consists the examples of theses from previous years.

According to the Study guide students should:

- Develop a project idea and submit it in time (with the support from course coordinator).
- Develop a project plan based on the project idea and submit in time (with the support from supervisor).
- Discuss with the supervisor to decide how the supervision will be implemented.
- Keep regular contact with the supervisor, report the progress and discuss encountered problems.
- Send the initial report draft (60% of the work) in good time (2-3 weeks before midway seminar) to the supervisor for feedback/comments. Based on the recommendation from the supervisor, upload for the midway seminar. It is also recommended to do an oral ***self-evaluation*** based on the learning outcomes of the course.
- Discuss with the supervisor on project report outlines at early stage to make sure that the report is well structured and organized.
- Do the ***self-evaluation*** based on the learning outcomes of the course and send the report draft together with the evaluation to the supervisor (latest one week before the final upload). Based on the recommendation or feedback from the supervisor, upload the final presentation.
- Submit various reports (mid-way seminar, final presentation and opposition reports) in time.

A self-evaluation is an important document that mainly helps students with the formality check, if all parts of the thesis are fulfilled according to the Degree project plan, if the thesis meets all the learning outcomes, and if it is in acceptable status and ready for presentation.

INVESTIGATION AND RESULT

In recent years, we observed that engineering students graduated but with a certain time delay. Since we did not have many students on the program, we wondered the reason for this delay and how can we improve it. In Sweden the students evaluate the course, but even in this evaluation we could not find any hints for improvement.

Investigation 1: Results from both courses during last 9 years.

During 2012–2014 both courses were offered as full-time studies, where the Systems Engineering was given before the Degree project. A reason behind that structure was that the students could concentrate only on one course during the time. However, students could not finish Degree project on time, mainly because 4 of 10 weeks were waiting time for an assessment of the project plan as well as the uploading final version two weeks before the presentation. It was not possible to go through literature study, implementation, experiment, measurement, analysis and summarizing the theory in practice in a written report during 6 full-time weeks. Most of the students did not catch a deadline for the first presentation.

From 2015 – the courses were run in parallel. For the Degree project, the waiting time was the same as previously, but the students had 16 half-time weeks (=8 full-time weeks) to work on the thesis. We could observe, that because the examination for Systems Engineering was held before the summer, the students put more efforts on this course and therefore more students finished Systems Engineering course compared to the Degree project course.

During 2015–2017 Degree project had three examinations possibilities: two before the summer and one during the autumn. From 2018 one examination before the summer has been moved to after the summer (to give the students the opportunity to gain access for the master's programme).

Figure 2 shows the number of students that passed both courses. There are three staples, the first (blue) represents Systems Engineering course, the second (orange) and the third (grey) represent Degree project with "Thesis - same year" (all three presentations) and "Thesis - later" (later year presentation) respectively. There are more students that completed Systems Engineering course. Only in 2017 all students passed both courses "on time", i.e., in the same year. However, these students presented the Degree projects in the last, autumn presentation.

From 2018 the students have a possibility of joining the courses. Already in 2018 most of the students presented the thesis on time. As mentioned, three remaining students put too many efforts on themselves and presented the theses one year after. We could observe similar behavior of ambitious students even during the 2019 presentations. In 2020 most of the students follow the recommendations from older students and we could see that most of them presented the thesis on time.

Investigation 2: Survey

The survey was conducted in the Spring term 2020. All engineering students were asked for a reflection after the presentation of the thesis. Furthermore, 8 students completed the survey. The overall reflection on merging both courses was very positive. The students agreed that it was a very good idea because they could concentrate on only one subject. The biggest challenge was to complete both courses on time. It is interesting to mention that the students agreed that if they were to repeat the courses, then they would do the same. Table 2 presents feedback from students about benefits and drawbacks of joining the courses.

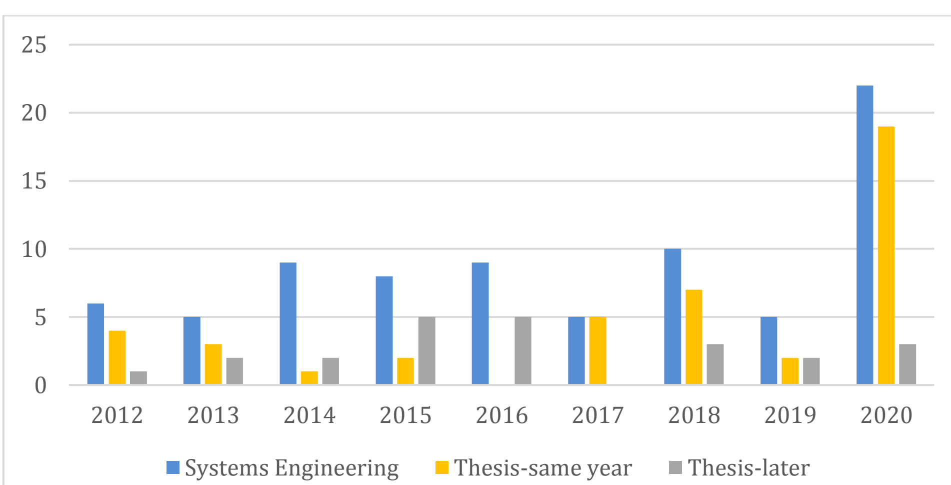

Figure 2: Number of students that passed two courses

Table 2. Benefits and drawbacks of joining the courses

Benefits	Drawbacks
Yes, because it's fun to really be able to immerse yourself in one and the same area, to be able to plan the entire semester with a purpose, and the successes become clear.	No, because it can be too demanding, hardware is difficult, and a lot can go wrong. In theory it is easy, but in practice it can be tricky and sometimes impossible - and in some cases absolutely not as you had imagined.
The benefits we observed was that we could spend more time thinking about the topic of the thesis. We got a lot of insight while working on the Hardware as much as when we were doing literature studies. This means we became well versed in the whole topic the limitations and needs of our project. This is why our thesis ended up lengthy as well because there was a lot of insight and knowledge we learned while working on the subject.	The drawbacks would be that if we failed one, we would very likely fail the other. As the two projects go hand in hand and the thesis depends on us having two functioning devices, we were taking a big risk. If we failed to finish the hardware it would be impossible to progress and evaluate its performance.
Able to focus full time on one project. Go deeper in one subject instead of half depth on two projects.	It was hard two divide the project in two, to separate what belonged to the SE and what belonged to the thesis.
For joining the courses together, we think it could be beneficial as we believed that it could give us more practice over multiple blades.	However, to be honest, the time that we spent on the courses have been way much more than we expected, sometimes, we have to study for more than 12 hours and even study during weekends (not kidding).
We think with the combination, we can save some time and effort on collecting information, carrying out the research to a deep Degree. We believed we definitely benefit a lot from the joint project, especially by working with the company, the social and business experience benefit us a lot and with the combined course, the research can be carried much deeper and wider in some Degree.	

SUMMARY

This contribution addresses problems related to the completion of a Computer Engineering program. Revisions of that program have been made, where this contribution in particular focuses on a conscious synchronization of courses during the last semester. By having a project course in parallel with the thesis, technical/practical aspects are integrated with more scientifically oriented aspects, and where a larger project connects these aspects. The results have shown a positive outcome in terms of number of students completing the last semester, as well as the quality of the performance. Furthermore, a survey shows satisfaction among the students, where the following quote gives a good summary: *In the end, it was a really good summary of all the courses […] included in our program. You got proof that you have been able to use the knowledge you have learned over the past 3 years - and done a big and demanding project with it all*. As we aim to push the students to conduct the courses, system engineering and thesis, outside the university in companies, we plan to involve these companies in future evaluations of the courses.

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SUSTAINABLE DEVELOPMENT IN CHEMICAL ENGINEERING CURRICULUM: REVIEW AND MOVING AHEAD

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ABSTRACT

The Diploma in Chemical Engineering (DCHE) introduced the teaching of chemical product design into its 3-year curriculum in 2009, which prepared the foundation for the subsequent integration of sustainable development into the curriculum. This paper presents a critical review of the changes in education for sustainable development (ESD) for the last 10 years, including the advent of Industry 4.0 and how it can impact ESD. The paper first outlines the general two-prong approach in DCHE, aimed at simultaneously satisfying the needs of the chemical processing industries for competent graduates, while at time same time made dual-use of available curriculum hours to enable students to use knowledge in chemical engineering to contribute to sustainable development using the CDIO Framework, with chemical products that meets the needs of the less-privileged at the bottom of the pyramid. The paper summarizes literature reviews of recent developments in ESD, why previous efforts did not lead to the desired results, as well as new challenges and opportunities afforded by Industry 4.0 technologies. The paper also discusses current view on sustainable development using a systems perspective; whereby sustainability is viewed as a dynamic system whose equilibrium is always disrupted. The framing on how ESD can be delivered also shifted towards a more transformative approach, by focusing on more on empowering the students, to prepare them in shaping their own views on the wicked nature of sustainability issues by taking into considerations the different and often-conflicting perspectives of various stakeholder, etc. An emerging approach in transformative learning is based on the theme of sustainability as a discourse. The paper then shares the findings from a recent survey of DCHE students on their learning experiences in chemical product design which had remain unchanged since the topic was introduced into the DCHE curriculum. The result showed that we had much to update in our approach to ESD in light of recent changes. The paper then presents an updated thinking on how DCHE can revised its coverage of sustainable development to move forward. The emphasis on teaching sustainable development is now directed towards preparing the learner, by equipping them with the knowledge, skills and attitudes that they need to negotiate and navigate the ever-changing sustainability landscape on their own. While retaining the same two-prong approach, the learning experiences will now be enhanced using the CDIO Framework to include competencies in using Industry 4.0 technologies in chemical processing as well as developing graduates with sustainable mindset who are able to contribute to sustainability well beyond their study in DCHE.

KEYWORDS

Sustainable Development, Chemical Engineering, Standards: 1, 2, 3, 5, 7, 9, 10, 11, 12

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

INTRODUCTION

The Diploma in Chemical Engineering (DCHE) in Singapore Polytechnic (SP) is a 3-year course that aims to prepare graduates for the chemical processing industries, taking up various position as process technicians, engineering executives, technical support officers, etc. DCHE introduced its revised curriculum redesigned using the CDIO Framework for the first time in April 2008 and had been finetuning the course content ever since. DCHE added chemical product design and development into its curriculum in 2009, to broaden the application of chemical engineering principles in response to changing roles of chemical engineering in the 21st century, and to enhance the employment prospects of its graduates (Cheah & Ng, 2010). Recognizing the need to better prepare the students to be able to contribute positively to sustainable development, the curriculum was revised again in 2011 to emphasize chemical product design that focus on sustainability issues (Cheah, 2014; Yang & Cheah, 2014; Cheah, Yang & Sale, 2012). The enhancements include the adoption of design thinking (Cheah, 2012; Ng & Cheah, 2012) and the use of appropriate technology in students Final Year Project (Chua & Cheah, 2013). Readers interested in the design principles and pedagogical approach are encouraged to look at these earlier papers.

The approach taken in the abovementioned changes used a 2-prong strategy, aimed at making "double duty of teaching time" (Crawley et al., 2007) to maximize students learning not only in technical know-how, but also acquiring the skills needed and developing the right mindset and attitudes – the "dual impact learning". In short, the 2-prong strategy, designed using the CDIO Framework, resulted in an integrated curriculum with 2 pathways, one – termed the "chemical process pathway" that prepared students in chemical plant design and operations, and another – termed the "chemical product pathway" in chemical product design and development. For the latter, we introduced a project-spine in the curriculum, which consist of a basic-level design-implement experience in Year 1, and 2 modules in Semester 1 and Semester 2 of Year 2 respectively, that focused on chemical product design and development, with flexibility of allowing students to propose the types of project that they wanted to work on as their capstone in Year 3. DCHE students henceforth are required to complete 2 major projects in their year 3 of study: a chemical plant design project and a capstone project (based on chemical product design). Students learnt various chemical engineering principles that support both pathways. Figure 1 represents our approach to Education for Sustainable Development (ESD) using a project-spined that is sustainability-themed. And more recently, we also included the explicit teaching of self-directed learning skills in students, with the aim of making them more independent in their study, to prepare them to become lifelong learners (Cheah, 2019).

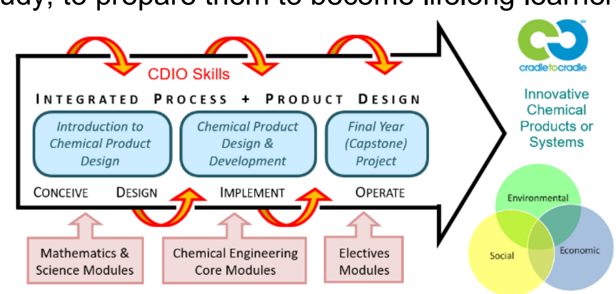

Figure 1. Integrated Curriculum for Chemical Product Design via Project-spine

As shown in Figure 1, various skills are also integrated and delivered via integrated learning experiences and active learning. The convergence came with the understanding that a chemical process can be designed to produce a particular chemical product. This is not realizable within the available curriculum hours for the design of specific process for the production of a specific product; so this topic was delivered to students via classroom lectures.

The objective is the dual outcomes of education, in that our students are able to: (1) use the learning gained to contribute professionally to their chosen discipline, to become valuable employees in the chemical processing industries who are competent in the workplace; and (2) use the same learning gained to contribute personally to efforts in sustainable development, to serve the broader needs of society, in particular to the less privileged at "at the bottom of the pyramid".

LITERATURE REVIEW: UPDATES IN ESD (INCLUDING IMPACT OF INDUSTRY 4.0)

Over the last 10 years, there had been major developments in the approaches to ESD. Questions had continually been raised on how much had ESD achieved in helping to meet the various objectives of the 17 UN Sustainable Development Goals (SDGs). A recent report from UNESCO summed up the findings: "……unfortunately not yet been possible to anchor sustainability in the teaching that occurs in higher education – apart from individual examples, such as Sweden, where higher education institutions are legally required to promote sustainable development" (UNESCO, 2017). Limitations of various approaches used had been highlighted, for example, over-emphasis of the use of technology (Segalas et al., 2010) in particular had been overly focused on addressing environmental issues. Mochizuki (2019) noted that education often places emphasis on preparing students for competitive participation in the global economy, rather than to become critical and responsible members of society in alignment with the objectives of ESD. Alvarez & Rogers (2006) noted that much of what is going on in sustainability education is prescriptive, for example in establishing environmental targets, audits, energy and water efficiency. In these approaches, the roles and views of students are neglected, in particular any prior knowledge that they had, and tend to prescribe "a right position" to sustainability issues. Rather than utilizing the complexity of sustainability subject matter to support student thinking, sustainability is being utilized as an opportunity to maneuver students into one viewpoint or another (Scarff-Seatter & Ceulemans, 2017).

Increasingly, an emerging view is to look at sustainable development with a systems perspective (Lim et al., 2018; Zhang et al., 2016): sustainability as a dynamic state that society is constantly trying to define and reach. Carew & Mitchell (2008) noted that understanding and identifying with a particular worldview among several should be seen as indicative of the contestability and complexity of sustainability studies. Kioupi & Voulvoulis (2019) suggested that sustainable development is to be considered as an end state: that the visions of an ideal, sustainable future as influenced by history and culture; where educational programs are indoctrination tools for achieving that kind of future. Sustainable society as a system state can only emerged as the result of complex interactions between system parameters and conditions with education guiding the transformational process for society in reaching such a dynamic state. The goal of higher education is now seen as supporting students in developing their capacity for recognizing and understanding the complexity of sustainability issues, and for thinking critically about assumptions, biases, beliefs, and attitudes while actively participating in their resolutions (Scarff-Seatter & Ceulemans, 2017). The aim of education would therefore be to prepare students who can: (i) develop sustainability attitudes, skills, and knowledge that inform decision making for the benefit of themselves and others, now and in the future; and (ii) act upon these decisions. In this view, students should no longer accepts any "uncritically assimilated explanation" by "experts" – rather, they are now seen as actors who can make their own choices and impact on sustainable development. Students should be allowed to make their own interpretations, rather than act on the "purposes, beliefs, judgments, and feelings of others" (Scarff-Seatter & Ceulemans, 2017). Students will be more open to and draw upon other views and possibilities: the "experience of seeing our worldview rather than seeing with our worldview" (Sterling, 2011). Such a learning is transformational in nature, involving perceptual change and coming to a transpersonal ethical and participative sensibility, or a shift towards a more relational way of seeing that inspires different values and practices.

To this end, transformational learning has therefore increasingly been conceptualized and operationalized in ESD (Aboytes & Barth, 2020; Laininen, 2019). Transformative learning evolved from the concept of perspective learning (Mezirow, 1978). According to Mezirow (2003), transformative learning is "learning that transforms problematic frames of reference – sets of fixed assumptions and expectations (habits of mind, meaning perspectives, mindsets) – to make them more inclusive, discriminating, open, reflective, and emotionally able to change". Several authors have elaborated the theory, but there is no uniform understanding of its content and no generally accepted definition for the concept (Laininen, 2019).

An outcome of transformative learning is that students developed "competence" to understand multiple ways of looking at the world, with an "ultimate goal" that integrates action into one's new view of the world; henceforth moving one towards a frame of reference that is more inclusive, discriminating, self-reflective, and integrative of experience. Sterling (2011) called such an approach as one that can "take us to the depth of things". We therefore decided on an ambitious (some may say audacious) goal of having our students develop a "sustainability mindset". Just like the words "sustainability" and "sustainable development", it can be used in multiple contexts. Kassel et al. (2016) defined it as a way of thinking and being that results from a broad understanding of the ecosystem's manifestations, from social sensitivity, as well as an introspective focus on one's personal values and higher self, and finds its expression in actions for the greater good of the whole. Hermes & Rimanoczy (2018) identified 3 dimensions of sustainability mindset: systemic thinking, innovative thinking and being. In the context of ESD, it can be developed as a new lens through which individuals can look into the world, analyzing data and making better decisions.

To achieve the desire learning outcomes, Mezirow (1981) described the key characteristics of transformative learning in terms of learning processes (how people learn), outcomes (what they learn) and conditions (how to best support their learning). There has to be a shift in teaching practice, from teaching about sustainability as though it was fixed and definable, to a way of learning about the multiple ways in which sustainability is contested and understood. There also need to employ teaching approaches that go beyond the cognitive domains, to focus on the affective domain: values, attitudes and behaviours (Shephard, 2007). In addition, there also need to engage students in reflective practice (Balsiger, 2017). Correspondingly, there is also a need for change in the role of educators: Not to tell students what sustainability was or ought to be, but rather to develop within them the capacity to interpret what it might be.

Over this period, the emergence of the so-called Fourth Industrial Revolution or Industry 4.0 is also driving changes not only in the manufacturing sector, but also in education, including ESD. However, one must note that the very notion of Industry 4.0 did not start with sustainable development: it has always been about improving productivity of manufacturing by leveraging on various technological advancement, e.g. Internet of Things, Big Data, Cloud Computing, Cyber-Physical System, etc. Knudsen & Kaivo-oja (2018) noted that although Industry 4.0 and its related technologies may facilitate more sustainable production, but sustainability is not an endogenous feature of Industry 4.0. Anadon et al. (2016) called for the need to make technological innovation work explicitly for sustainable development. While some authors spoke on the opportunities afforded by Industry 4.0 on sustainable development (e.g. Ordieres-Meré et al. 2020; Klymenko et al. 2019), others such as Kohtala (2015) noted that these are not a given, that there will be new, clearly cleaner production paradigm.

There are positive findings reported on how Industry 4.0 can contribute to sustainable development, but the transition to Industry 4.0 does not automatically leads to sustainable development. Equally there are reports of negative impacts, that increased technology update can also happen unsustainably. Olav et al. (2020) for example, summarised reports from various sources on the positive impact of how Industry 4.0 added values to consumers (better experience, enhanced customization, reduced cost) as well as to companies (improved efficiency, boosted synergy). On the other hand, Bonilla et al. (2018) reported on findings from various studies of the negative impacts of various elements of industry 4.0 (automation, integration, digitization) on the environment. Ally & Wark (2019) noted that little research has been done on the short- or long-term consequences of applying Industry 4.0 technologies in practice. Kiron & Unruh (2018) called the convergence of digitalization and sustainability as leading to the “perfect transformative storm”.

REFLECTION ON WORK DONE: SURVEY OF STUDENT EXPERIENCE IN ESD

The current approach to ESD based on Figure 1 had been running since its introduction into the DCHE curriculum in 2011. This model of execution had remained largely unchanged and after the initial surveys where sustainable development was introduced (the findings of which are presented in earlier works: see Cheah, Yang & Sale, 2012; Chua & Cheah, 2013), students were no longer asked on how they find learning about ESD in this manner. From 2015 onwards, the entire teaching team, are all caught up in other initiatives such as responding to changes brought on by Industry 4.0 (e.g. Yang & Cheah, 2020; Cheah & Yang, 2018) and changing students’ dispositions necessitating the use of different approach to teaching and learning such as flipped classroom (e.g. Sale & Cheah, 2017; Cheah & Sale, 2017; Cheah, Sale & Lee, 2016). There is also a new initiative to make students more self-directed in managing their own learning (Cheah, 2020; Cheah, Wong & Yang, 2019). All these works inevitably resulted in a certain degree of ‘neglect” of ESD; as every module coordinator try to cope with the more immediate changes affecting his/her modules.

To catch up on our students’ learning experience in ESD, in particular in light of the recent developments in ESD, in September 2020 and February 2021 we conducted a brief survey on 2 cohorts of our Year 3 students (each about 60 students) on how they perceived ESD over the 3 years of studying chemical engineering in SP. The survey is administered over and above other surveys students are asked to complete, at both institutional level as well as national level mandated by the Ministry of Education of Singapore. This arises from the unprecedented COVID-19 pandemic, affecting student learning due to campus closure (complete or partial; depending on which point in time). To minimize student “survey fatigue” we kept the questions on ESD to a minimum to make room for other questions within the same set of questionnaire.

The questions on ESD and student responses (total 70) are shown in Figures 2 to 5. It can be seen that our students acknowledged the importance of sustainable development (Figure 2, with average score of 8.56) and a large percentage of them (48.57% who indicated ‘to a moderate extent’ and 27.14% who indicated ‘to a good extent’) are able to make use knowledge in chemical engineering to contribute towards sustainable development (Figure 3). On the other hand, it is clear that not all our Capstone projects are sustainability-themed

(Figure 4) due to the fact that we also take on some industry-sponsored projects the scope of which are already defined by the companies. Also, the extent to which sustainability elements are included also depends on how the project is scoped. It is heartening to see some students reported that they see opportunities for their projects to be linked to sustainable development even though this aspect is not part of the project scope (Figure 3). Overall, the majority of students still reported that they are satisfied with the coverage of sustainable development in the curriculum (Figure 5).

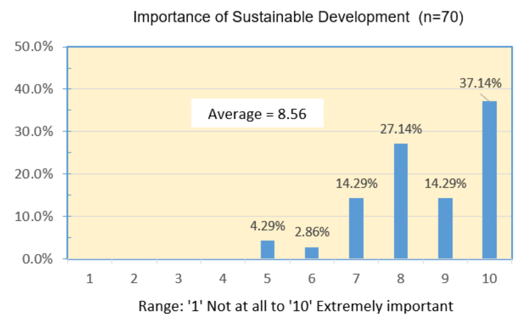

Figure 2. Importance of Sustainable Development

Q1. This question pertains to modules that cover chemical engineering core principles such as fluid transfer, heat transfer, separation processes, process instrumentation and control, and chemical reaction engineering. It does NOT include modules on chemical product design. To what extent do you think DCHE had prepared you to contribute to sustainable development? Choose ONE that best matches your perception.

(a) Not at all - I don't recall I've been taught anything on sustainable development

(b) To a limited extent - I have some ideas on sustainable development but don't know how to use what I learnt

(c) To a moderate extent - I can see how some of the core principles taught can be applied in sustainable development

(d) To a good extent - I believe I am able to use these core principles that I have learnt for matters related to sustainable development.

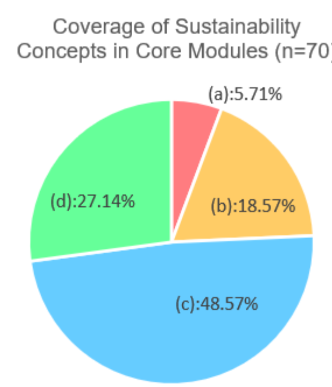

Figure 3. Coverage in Core Modules (not including modules in project spine)

Q2. Is your FYP related to sustainable development? Choose ONE that best match your experience from completing the FYP.

(a) Not at all

(b) Maybe. I am not sure. It is not clear to me

(c) Yes, but only a limited extent: it has application in sustainable development, but I am not working on that aspect

(d) Yes, to some extent. Some aspects of it has applications in sustainable development.

(e) Yes, my FYP it is all about sustainable development.

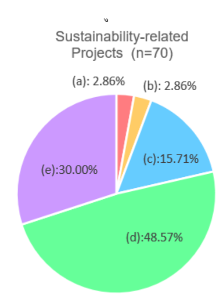

Figure 4. FYP with elements of Sustainable Development

Q3.Overall, in relation to your answer to Question 1 on importance of sustainable development to chemical engineering, are you satisfied with the coverage of sustainable development in the DCHE curriculum? Choose ONE that more represent your sentiment.

(a) Not satisfied at all
(b) Not very satisfied
(c) Somewhat satisfied
(d) Satisfied
(e) Very satisfied

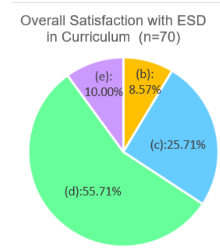

Figure 5. Overall Satisfaction with ESD in DCHE Curriculum

Reflecting on our effort over the past 10 years, we can modestly claim that we had had some success at instilling a "can do" spirit among our students: by building on their intrinsic motivation, we had given our students the confidence to make a difference using the knowledge that they gained. We therefore conclude that the approach we put in place for the "dual pathway" is working; and identified several shortcomings that need to be addressed. There is still a significant number of students (5.71%) who reported that they did not see how sustainability had been covered in the various core modules (Figure 2). Also a significant number (18.57%) reported that they do not know how to use what they learnt (Figure 3). Lastly, there is still a small number of students (2.86%) being not very sure if their project is related to sustainability (Figure 4). When compared to our initial aim at integrating sustainable development into the DCHE curriculum, the results showed that we had fallen short. Our aim then is to strive to achieve what is termed as "third-order learning or transformative learning" (Sterling, 2004) as shown in Table 1.

Table 1. Three Levels of Education in relation to Sustainability

Education about sustainability	First-order learning Emphasis is on content/knowledge-based learning within the dominant paradigm Assumes that meaning of sustainability can be clearly identified and taught as a separate subject Essentially 'learning as maintenance' of current paradigm
Education for sustainability	Second-order learning Emphasis is on 'learning for change' that includes content, but goes further to include values and capability bias Deeper learning: involves critical and reflective thinking about sustainability Assumed that we know clearly what values, knowledge and skills 'are needed' for change and while challenging the existing paradigm leaves it mainly intact
Education as sustainability (Sustainable Education)	Third-order, transformative learning Emphasis is on process and quality of learning, which is seen as an essentially creative, reflective and participative process Knowing is seen as approximate, relational and provisional, and learning is continual exploration through practice Shift is towards 'learning as change' which engages the whole person and learning institution Process of sustainable development or sustainable living is essentially one of learning, while context of learning is essentially that of sustainability

What we can conclude from our efforts at ESD to date, is that we have yet to achieve the transformative learning that we aspire. At best, we just reached the lower "threshold" of second-order learning, meaning that our approach to ESD had met some elements of second-order learning, but had not fully embraced what it entailed. Falling short for example is reflective thinking about sustainability. We do not make is an explicit requirement that students in such practice as part of their capstone project work. There is also no explicit effort in discussing the needed values for transformative change. We are still locked in existing paradigm. As noted by Sterling (2011), learning that took place within an existing paradigm does not change the paradigm, whereas learning that facilitates a fundamental recognition of paradigm and enables paradigmatic reconstruction is by definition transformative. There are more to be done.

MOVING AHEAD: IMPROVING ESD IN CHEMICAL ENGINEERING CURRICULUM WHILE MAINTAINING THE DUAL PATHWAYS

There is a need to have renewed efforts aimed at raising greater awareness among students on various issues related to sustainable development, to promote a stronger ‘bias-for-action’ among students. Aboytes & Barth (2020) noted that if used appropriately, transformative learning can contribute to the design and implementation of educational interventions and assessments of learning towards sustainability. We are now in the process of revisiting the CDIO Framework to work out the required competencies in particular the affective domain. The aim is to reinforce current approach of learning via projects supported by other modules (Figure 1) to develop new competencies required for Industry 4.0 and ESD.

This requires us to go beyond the typical integration of skills widely covered in our integrated curriculum such as Teamwork and different forms of Communication, namely oral, written and graphical. We need to strengthen existing coverage of CDIO Syllabus Part 2.3 *Systems Thinking* and Part 4.1.6 *Developing a Global Perspective*; as well as other aspects of Communication that includes 3.2.7 *Inquiry, Listening and Dialog*; 3.2.8 *Negotiation, Compromise and Conflict Resolution*; and 3.2.9 *Advocacy*. We also need to also include other personal and professional skills and attributes that, to date, received little attention. These include Part 2.4 *Attitudes, Thoughts and Learning* (for example 2.4.1 *Initiative and Willingness to Make Decisions in the Face of Uncertainty*; 2.4.2 *Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility*) and Part 2.5 *Ethics, Equity and Other Responsibilities* (for example 2.5.1 *Ethics, Integrity and Social Responsibility*; and 2.5.5 *Equity and Diversity*).

These parts of the CDIO Syllabus will serve as learning outcomes to be mapped to the skill sets required for Industry 4.0 and sustainability mindset. This will then guide the redesign of our integrated curriculum, integrated learning experiences, learning assessment, faculty teaching competency and program evaluation. In our context, for skills and attributes required for Industry 4.0, we took reference from the Singapore Skills Framework, which are captured in 16 critical core skills (Mercer & SSG, 2020). For sustainability mindset, the approach of sustainability as a discourse shall be used, and students can be engaged in discussing about sustainable development in the context of chemical engineering. Ideas for chemical products can be tied explicitly to addressing one (or more) of the 17 Sustainable Development Goals (SDGs). In all these endeavours, skills and attitudes associated with the affective domain as mentioned in the previous paragraph can be integrated, over several stages of study to the required proficiency level consistent with DCHE’s spiral curriculum course structure (Cheah & Yang, 2018). Detailed discussion of these works is beyond the scope of this paper and will be shared at future conferences. An example of our approach will be provided in the subsequent paragraphs.

More specifically for ESD, we shall adopt the approach to transformative learning by Scarff-Seatter & Ceulemans (2017) who position it as a process that:

(i) allows students to question taken for granted frames of reference to become more discriminating, open, and reflective
(ii) produces major changes in thinking, feeling, acting, relating, and being

(iii) allows for evaluating values and assumptions for their effectiveness towards shared goals

With regards to how best to support students in their learning, we will adopt the approach suggested by the same authors (Scarff-Seatter & Ceulemans, 2017) to treat *sustainability as a discourse*; referring to sustainability issues as a contested discourse that is spoken and claimed by competing groups and cultures, rather than a concept that can be pinned down and identified in the real world. This approach is in line with our dual outcome approach to education alluded to in the earlier paragraph. We remain committed to prepare our students for the profession and industry they are trained for, while at the same time, equip them with the mindset that allows them to resolve any "dissonance" (Kagawa, 2007) in the sustainability issues that they are facing.

The author opined that the topics that can lend themselves easily for this approach shall be those that posed the most controversies, i.e. "wicked problems" (Ritter & Webber, 1973). Such issues has the following characteristics: incomplete or contradictory data/information, many stakeholders with different interests and opinions, interconnected, and costly to resolve. To illustrate the proposed approach, we shall use the 'classical' debate of food vs. fuel, which from the point of view of sustainable development goals, can involve Goal No.1 *No Poverty*, Goal No.2 *Zero Hunger*, Goal No.7 *Affordable and Clean Energy*, and Goal No.15 *Life on Land*. The 2 skills that we will use to illustrate our approach are "sense-making" (described as "leverage sources of qualitative and quantitative information and data to recognise patterns, spot opportunities, infer insights and inform decisions") and "digital fluency" (described as "leverage digital technology tools, systems, and software across work processes and activities to solve problems, drive efficiency and facilitate information sharing"). They are chosen because they are applicable to both Industry 4.0 and sustainable development, and also able to support the attainment of learning outcomes identified earlier, e.g. CDIO Syllabus Parts 2.4 and 2.5. These 2 skills are complementary in nature and should be taught simultaneously, and progressively developed using the DCHE spiral curriculum course structure. The availability of massive amounts of data arising from adoption and implementation of Industry 4.0 technologies (e.g. smart sensors) means that both engineers and technicians must be able to make sense of what all these data implied. They must also possess the right data handing skills, such as data manipulation, validation and visualization to gain useful insights from the data for decision-making.

Both sense making and digital fluency can be contextualized and integrated into the DCHE curriculum straight from Year 1 Semester 1. For example, in the module *Introduction to Chemical Engineering,* students can be taught to use sense making skill in discussing about food vs fuel, for example in understanding different perspectives from various stakeholders, in discerning claims or counterclaims from both proponents and opponents in the debate. They can also learn about data manipulation and visualization, from experimental works in the module *Laboratory and Process Skills 1*. Moving on to Year 1 Semester 2, they can hone their data management skills, this time focusing on data validation of their experimental results in the module *Laboratory and Process Skills 2*. They can learn about the efficacy of biofuel production from different sources (for example, via seeds or nuts) in *Chemical Engineering Thermodynamics*. Then, in Year 2 Semester 1, students will take the module *Introduction to Chemical Product Design*, where they can look deeper some published figures of food price index, biofuel prices, etc as part of literature review on the impact of their proposed chemical product. This can be further reinforced in Year 2 Semester 2 in the module *Chemical Reaction Engineering*, where students can be engaged in further discussion on the role of technology in addressing the issue, e.g. improving the yield of food crop or greater conversion of biofuel. This in turn can impact the design choices in Year 2 Semester 2 module *Chemical Product*

Design and Development. In addition, students also learn the operation of various pilot plants in the Year 2 modules *Process Operation Skills 1* and *Process Operation Skills 2*; whereby they need to make sense of the data generated from the plants from the various smart sensors and instruments. These modules are also mutually supportive of 2 other core modules, *Separation Processes and Simulation* and *Chemical Engineering Design Calculations*. Discussions on sustainability issues can be bult into the learnings, via case studies for example the necessity of fuels to enable chemical plant operations on one hand, and flaring (i.e. burning off) of excess gases produced during plant operation vs. recovery of these gases as fuel. This is then enhanced by integration of Industry 4.0 technologies that makes use of data analytics to look at sources of fuel consumption vs generation to improve plant operation. The 'convergence' come in the form of plant design project that students need to complete is Year 3, which is from the module *Plant Design, Economics and Sustainable Development* and final year *Capstone Project*. The former is positioned to develop students as professionals needed by the chemical industries, with sustainability mindset to better understand the impact of technological developments on plant operation from a sustainable development perspective, vis-à-vis their roles and responsibilities as a chemical engineer or technician. In this manner, they can develop to become useful individual with sustainability mindset that allows them to negotiate and navigate the sustainable development landscape (as a dynamic system) that continues to unfold, well beyond their study in SP, to contribute positively to sustainability.

Lastly, in order to deliver the redesigned curriculum, one main key challenge is how to train lecturers to facilitate the discussion that is required using sustainability as a discourse, along with the assessment of the attainment of the desired learning outcomes. As noted by Lange (2004), sustainability education is not easy and few educators have training in how to do it, primarily due to its interdisciplinary nature (e.g. social sciences, psychology, etc), which is uncomfortable for lecturers. We need to carry out further research into this area, in order to prepare suitable professional development programs for our lecturers.

CONCLUSION

This paper provides a quick review of the recent ESD landscape that help shaped the approach to improve the integration of sustainable development in the chemical engineering curriculum, while simultaneously also addressed the curricular changes needed to better prepare our students for the post-Industry 4.0 working environment. The approach sets a high bar that aimed to develop sustainable mindset among students, using transformative learning. This will done through strengthening the current approach that maximize available curriculum hours to simultaneously develop competencies need for both Industry 4.0 and sustainable development, by identifying skill sets common for both. An example of such "dual impact learning" can be achieved using sense making and data fluency is shared. Much work remains to be done. However, we remained optimistic that the thoughtful application of the CDIO Framework will provide the necessary guidance need to navigate such a challenging endeavour.

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USING CRITIQUE TECHNIQUES TO IMPROVE PROGRAMMING SKILL

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ABSTRACT

Certain teaching methods may be effective in dissemination of subject knowledge across students but at the same time, the same method may not be that useful when applied to other subjects. For creative subjects like visual arts, the use of a standard academic checklist to ascertain knowledge acquisition may not prove to be effective in tracking students' artistic developments. In such a case, a preferred teaching strategy would be the use of unbiased feedback and comments to review, discuss and reflect on how much the students have made meaningful connections of their own learning. Conducting critique sessions may accentuate success in attaining set learning outcomes. This technique was piloted and used in a First-Year programming module "Fundamentals of Programming" at Singapore Polytechnic. This was to provide students with an integrated learning experience that allows acquisition of the necessary competence in understanding and applying programming knowledge and concurrently developing personal and professional skills such as communication, giving / receiving feedback and computational thinking. A key outcome is that students will learn the importance of writing well-constructed efficient programming codes with ideas generated from alternative approaches. This is an essential disciplinary skill of an IT professional in the rapidly expanding technology industry. This paper also shares how adjustments are introduced in student engagement and the learning environment in response to the COVID-19 pandemic.

KEYWORDS

Critique techniques, Peer learning, Problem solving, Programming, Virtual workspaces, Standards: 1, 2, 6, 7, 11 and 12.

INTRODUCTION

Learning to write programming codes requires both problems solving skills and knowledge of the notation syntax of a programming language. Based on the problem statement, the programmer selects appropriate control structures to perform sequential processing, selection for decision making, and iteration for repetitive control to produce an algorithm to solve a problem. Often this process can result in coming up with many possible solutions. This is because the same problem regarding the control structures can be designed and put together in various ways. Upadhyay (2020) proposed that a good computer program is not just about running flawlessly without any errors. Good programmers should also look into the adoption of best practices in writing efficient programs so that the codes are maintainable, extensible and easy to understand in the final design.

In the School of Computing, all First-Year students are required to take a common module ST0502 Fundamentals of Programming in semester 1 as a foundational IT module. The skills and knowledge learnt serve as building blocks for advanced programming modules in their studies, which eventually train them to be infocomm professionals in areas such as Software & Applications, Cybersecurity, AI and Data Science/Analytics to meet the demand of the IT industry.

Students taking programming for the first time often spend much time learning the programming concepts, language syntax and writing codes to solve a given problem. It has been observed during class exercises that some students struggle to develop the required basic algorithm. There were others who had completed the class exercises but may not have been aware of other better solutions that can run more efficiently than what they have derived. In a typical programming class, lecturers review the exercises of their students and will use one or two solutions to explain how concepts and programming constructs are applied. Students will then carry on completing the rest of the class exercises without going through any comparative evaluation for alternative solutions. The unfortunate thing is that the students will miss out valuable opportunities to explore possibly better solutions. This missed opportunity to deep-dive into a wider perspective to other solution offerings minimizes their chances to realise their weaknesses in programming techniques. This gap in the learning experience compelled the author to reflect critically on her own teaching practice, which led her to explore further on how group and peer critique techniques can be effectively employed as a form of formative assessment in CDIO context that can enhance students' learning on a technical module related to programming fundamentals. This can also assist to develop the students' attitude and skills in becoming competent and reliable IT professionals.

Due to the COVID-19 pandemic, all lessons adopted a fully Home-Based Learning (HBL) approach at the start of the 2020 new academic year and lessons were conducted synchronously using Microsoft Teams online platform. As such, instead of addressing the physical learning space of CDIO standard 6, the virtual online space was used as the platform for students' learning. It was also an opportune time to explore using a structured critique methodology by the author and students involved in this programming module.

LITERATURE REVIEW

Learning to program requires the understanding in the application of the various computer language syntax. But it has been observed that the competency required of a good programmer lies more towards having the effective knowledge of problem-solving skills (Sprinkle & Hubbard, 2012). Although the proper use of language syntax is still an important factor when teaching students about programming, their problem-solving skill will play a bigger role to ensure a higher success rate of writing efficient codes for the programs to run successfully and efficiently.

In any problem-solving scenario, the expected outcome is to attain a positive and workable end result. Programming is about writing the steps that follow a set of rules that is the algorithm (Miller & Ranum, 2013). Writing a good algorithm to a problem will determine the resource efficiency in getting the final desired result. This would rely very much on the ability of the programmer to do the correct problem-solving process to derive an expected outcome.

There is a myriad of problem-solving tools that can be effectively used in group setting to productively brainstorm and come out with a solution to a stated problem. One of the most effective ways is to create a non-threatening environment to facilitate ideas generation that the students in the group can share (Smart, 2020). In this respect, a facilitator like the teacher can use action dialogue with the students in the form of constructive critique to draw out their learning to be shared. This is widely used in design studio education as it is an essential mode of assessment West (2015). This form of brainstorming will encourage active participation to understand and be exposed to the problem-solving process within teacher-students and peer-to-peer critique sessions. Utaberta et al. (2020) distinguished interim critiques as being educational in nature where students receive feedback to improve on their works as opposed to just using critique for the purpose of assessing performance / knowledge only. These interim critiques range from relaxed chats to more stressful forms such as individual, formative, peer, group, public, written, seminars to panel critiques, which if conducted properly will bring about meaningful learning.

In his expounding on Constructive Alignment (Figure 1), Biggs (2003) argued that students learn best when they are able to construct their own learning with the appropriate activities that are able to anchor their learning. In this respect, Biggs continued that educators would need to create learning environments that can support these learning activities in order to achieve the desired learning outcomes. Much of Biggs' work is founded on the belief of the much earlier works of Tyler (1945) who claimed that active learning behaviours are what will help students to learn. The introduction of critique sessions is an activity to facilitate this learning. The giving of good feedback is one way to significantly contribute towards Constructive Alignment (Gallagher, 2017).

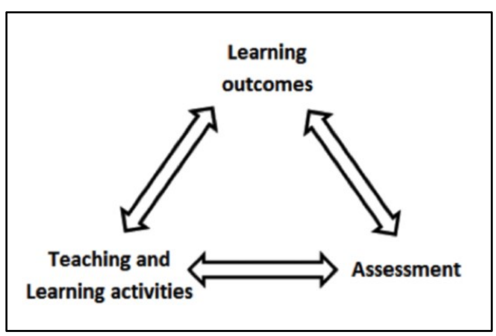

Figure 1. Constructive alignment

Chandrasekera (2015) recognized this and mentioned that "Design critiques, sometimes referred to as design juries or design reviews, are used both as an educational exercise as well as an evaluation tool and have been used in design education for more than a century." Our focus here is towards this evaluation purpose and so that critique techniques are used as a "knowledge building tool" for the students. In any conventional teaching and learning environments, the teachers will always have the control on the subject matters on how and what are to be taught. With critique as a learning tool, the offering of constructive feedback for students by the teacher or from fellow students may give greater meaning to what is needed to be better understood. This can offer an improved level of authentic learning for the students.

Friese (2015) described a range of critique methods that can be effectively employed in teaching and learning. Although Friese's area of expertise is in Art and Design, she proposed that critiques are a methodology that can be employed to achieve learning outcomes of most subjects when it is properly applied. This paper will select some of these critique methods that will be modified and managed accordingly to suit the HBL environment when conducting the module.

METHOD

The study consisted of three classes of First Year students from three different Diplomas. A total of 62 students were in the program participating in this study: 19 students from Diploma in Common Infocomm Technology Programme, 20 students from Diploma in Infocomm Security Management and 23 students from Diploma in Information Technology.

The module ST0502 Fundamentals of Programming was conducted twice a week synchronously online lasting three hours each. Students in each class are divided into smaller online groups consisting of four to five student members. Using the feature of Teams Channel, each of these groups were placed in an online “breakout room” within Microsoft Teams software.

As this was the commencement of the new academic year, most of the First-Year students were new to each other. It was observed that most were “shy and unfamiliar” to articulate during the online discussions. As compared, it will not be a very different scenario if the same session is to be conducted face-to-face. The other point to note which is also important is to prepare a safe non-threatening environment to conduct the critique sessions. To ensure the rationale and importance of each students’ participation, the lecturer briefed the students on the purpose and the advantages of the critique sessions that would be incorporated during the lessons.

A typical lesson will involve the lecturer to teach the concepts and knowledge using online synchronous lecture lasting about 30~45 minutes. Students will use the remaining lesson time to complete the module exercises. These were mainly tutorials and practical exercises that included topical self-check quizzes to be done under the supervision of the lecturer.

Upon completion of the online synchronous lecture, the students will ‘go’ to their respective online “breakout rooms” to do their exercises. During this period, the lecturer will navigate from “room to room” virtually to assist and check on the students’ progress. Once the group has completed almost half the exercises, the lecturer acting as the facilitator, will initiate the critique session.

Typically, two types of critiques were carried out: Peer and Group. Peer critiques were facilitated by students with minimal lecturer’s supervision. For the group critiques, the lecturer was the facilitator. In both experimental techniques, the lecturer selected the tutorial and practical questions for critique. The students took turns to present their solutions by sharing their presentation screens using Microsoft Teams. The lecturer started off the group critique with easy questions and demonstrated how to give constructive feedback, and emphasized the importance of being open and confident in speaking in class. In addition, students who were still unfamiliar or uncomfortable to participate during the critique sessions were guided by the lecturer. Questions asked can range from approaches to the problem, reasons for constructing the programming codes, rationale for selecting a particular programming technique or anything related to the solution presented by the student or others. The sessions then progressed to more difficult and complex scenarios as the students became more confident in articulating their answers according to their understanding. Once the group was observed to have traction to the critique process with the students able to facilitate each other to look at the programming problems and issues for that topic themselves, the lecturers will exit from the group. The students will continue on with their own peer-to-peer critique. The lecturer will move on to another group and repeat the same process until all the students in the class have participated in the critique within their groups.

At the end of the term, two online surveys were conducted concurrently to gather students' feedback on their learning experiences. One was at SP campus level for all modules comprising standard questions designed for all courses and the other was conducted by the lecturer for her three classes only. Customized questions were designed to gather feedback on the use of critique techniques for only these students taking Fundamentals of Programming module.

FINDINGS AND DISCUSSIONS

To determine the effectiveness of critique in learning programming, the students completed an online survey created using Microsoft Teams forms. 60 students responded to the survey. Key summary of findings and discussions of the results are as follows:

98.3% (Figure 2) agreed that critique sessions were useful for them to gather feedback on their solutions and to learn alternative solutions to solve the same problem. This indication suggested that the students learnt much from the feedback that they obtained from the lecturer and fellow classmates when they presented their solutions to the group. By having the Q&A activity, it helped to clarify their understanding and efficiency of the different programming constructs used by other students in comparison to their own solutions. The lecturer noticed that students with a programming background contributed and shared programming knowledge/contents beyond the module syllabus.

93.3% (Figure 3) agreed that they were more confident and seemed not afraid or shy to show their working solutions to others. The fact that they received constructive feedback that have helped improve their solution was encouraging. On the same note, if the critique was more of a criticism, it may have highly dampened the students' morale instead. Only 6.7% of the students did not feel confident. Thus, further investigation is needed to determine the reason for this. The lecturer observed that over a period of time, those students who perceived their works were being "confronted", slowly developed confidence and were more forthcoming in presenting their solutions to others. These confident and openness attitudes are important attributes of an IT professional.

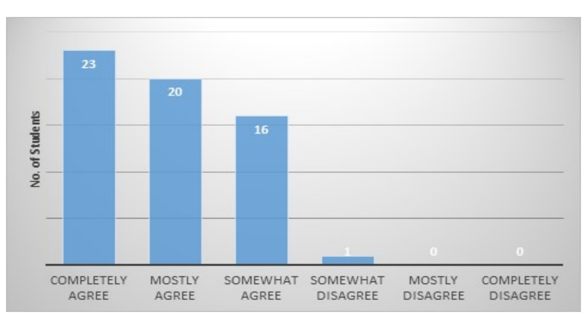

Figure 2. Responses question on usefulness of feedback

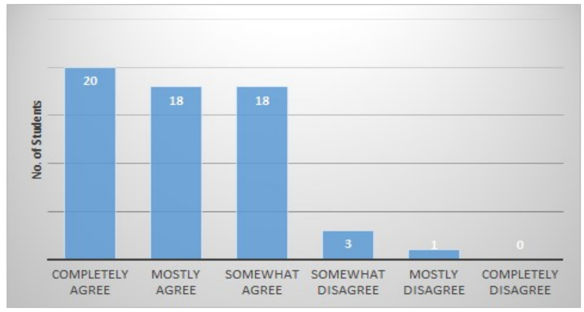

Figure 3. Responses to question on confidence in showcasing students' work

As First Year students are new to each other, the students may not be accustomed and comfortable to pose questions even during a face-to-face setting within a big class. For the sessions that were conducted online, 91.7% (Figure 4) of them agreed that they could learn positively from one another and to discuss problems in the smaller settings that have been organized for them. It was observed that students spoked and shared more openly in their breakout rooms. These small group online social spaces seemed to have offered greater opportunities for group members to interact and bond better. Only 8.3% did not find the small breakout groups useful. Further study can be conducted to investigate why they were not able to learn in smaller group settings and what can compel and motivate them to do so.

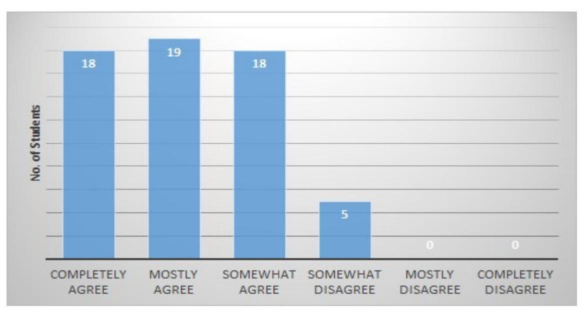

Figure 4. Responses to question on usefulness of breakout session

An open-ended question was asked regarding students' overall learning experiences in the module. Below were some of the comments collated on how the critique sessions have helped to motivate their learning:

> *"I was able to clarify my question with my classmates during breakout sessions and learn the way they used to code."*
>
> *"I had a chance to experience different kinds of problem-solving methods and it was a good mental exercise."*
>
> *"I like the breakout sessions because I can talk to my classmates and learn from them."*
>
> *"When we break out into our groups, the classmates are actually very helpful in trying to help me with the codes."*
>
> *"...the time was well spent on further reinforcing the concept through trying out the practical for myself and discussing methods of solving the question with my classmates."*

In the separate campus wide HBL survey which was carried out concurrently at the end of the term, similar positive feedback was received on the usefulness of critique in learning programming:

> *"We are able to critique our classmates' work and observe different logical processes."*
>
> *"I honestly felt like I learned alot when the lecturers interacted much with the students and showing our solutions to them during class allowed the whole class to give feedback."*
>
> *"We have group discussions mostly for every lesson and I think it is a good way for learning as I can clarify my questions from my lecturer and peers."*
>
> *"I like that the lecturer created breakout groups in this module so that the students can discuss and clarify feedback from the lecturer in a small group."*
>
> *"It is fun doing the practical and figuring out how to use different codes to achieve different outputs."*

For the Fundamentals of Programming module, a change on how students can be taught was taken into account since it has to be conducted home-based via online. To ensure that the students' understanding who have now to be taught online are still comparable to previously sessions engaged on-site, the critique model was used on selected batches of First Year students to survey their understanding. The initial survey has shown that conducting the facilitator-led critique followed by peer-to-peer among the class group are positive and have beneficial goodness for both the lecturer and the students. Technology has played a part to offer a conducive environment to be able to create "non-threatening rooms" for students to be placed into for the critique sessions. This offered a more comfortable smaller group space for them to participate in giving comments to each other's work. However, the downside was occasional internet connection problems may disrupt learning/discussion.

Both qualitative and quantitative feedback gathered did suggest that critique techniques have been mostly useful in assisting the students to learn this programming module, alongside developing their skills and attitudes of an infocomm student. The results also suggested that through the critique sessions with Q&A and offering constructive feedback, most students can learn more with understanding and meaning besides enjoying the interactions with fellow students. It also serves as a form of formative assessment for learning for both students and lecturer. The critiques contributed by students provide ongoing feedback to the lecturer on the students' progress and understanding. This way, the teaching can be appropriately adjusted to improve desired learning outcomes (Cambridge Assessment International Education, 2020).

The future of HBL may be more than just an option in the future for tertiary education. To cater to the use of this mode of learning, the critique model can be expanded further with emphasis on CDIO on its useful features:

1. To enhance the integrated learning experiences by inviting industry professionals for the critique sessions. Field trips or short attachments to infocomm companies provide great opportunities for students to learn about attitude, skills and technical knowhow within the industry.
2. To infuse critiques as a learning activity to align with the learning outcomes of the programming module and assessment for all Fundamentals of Programming classes that can encourage active participation from students to have deep engagement with the learning materials (Biggs & Tang, 2011).

3. To promote the usage of critiques as an effective learning activity that can be applied appropriately for the other modules in the School to enhance students' learning.
4. To design easy but more detailed evaluation tools that can measure and provide the effectiveness of critique sessions in enhancing students' learning quality.

To facilitate a non-biased adoption in using the critique methodology with the academics, lecturers have to be offered ample resources and assistance to prepare themselves if they are neither confident nor comfortable. For example, a meaningful critique session will certainly desire a higher ability to use questioning techniques and facilitation skills during the teacher-students interaction. Inevitably, there will be some other competencies that will be important to manage critique sessions smoothly. The development of these competencies can be raised with relevant training/sharing of activities:

1. Organize community of practice feedback/sharing sessions among teaching teams to sense and gather concerns of staff in using critiques for their lessons. The information gathered can be collated to develop the appropriate form of critique session to be introduced for specific classes.
2. Conduct short courses to equip teaching staff on the critique model and the techniques that can offer lecturers the ways to assess students' thinking processes and encourage articulation of their understanding / ideas / thoughts.
3. Build individual staff capability through peer observation among the teaching team, to learn from each other's teaching practice and provide constructive feedback for professional development and personal reflection (Department of Education and Training Melbourne, 2018).
4. Document reference guides for staff and students to be familiar with the attributes and cooperative actions required. This is to manage productive critique sessions for their respective teaching/learning e.g. teaching lesson guides with sample critique facilitation questions to avoid sporadic and unstructured critique sessions.

CONCLUSION

The current COVID-19 pandemic has initiated a time of serious reflection for business deliverables in both the public and private sectors on what's next for a New Normal. The education industry has also not been spared from re-looking at its delivery model for teaching and learning in a situation where alternate forms of educational interactions have to be introduced. Even with the advancement in educational technology over the past couple of decades, teaching and learning are still mainly conducted within an onsite face-to-face scenario between the teachers and students. No matter what the situation is, the challenge is always to ensure an effective content delivery system to provide interactive and meaningful individual learning seamlessly.

This paper examined the application of constructive critique in the teaching and learning of a programming module in providing an integrated online learning environment for students with respect to various CDIO standards. Students who were more self-directed and understood the lessons generally will have no problem participating productively during critique sessions. They are quite spontaneous in sharing and learning from one another. The peer-to-peer feedback also provided these students to generate greater ideas upon what they already know. In a way, the critique sessions have expanded their knowledge, not just through what was officially delivered but also by the engagement of ideas with one another. On the other hand, students struggling with the module may not be able to articulate as well during the critique sessions. But with appropriate prompting by the lecturer, they gained greater confidence and begin to engage with the rest of the class on the subject content. Although a longer period of time may be required and encouragement from the lecturer as the facilitator, these sessions will ultimately assist these students to develop their understanding further regarding what are required to be competent in the subject area. It will also greatly help to direct them in the right path through the participation in the students' feedback to clear their doubts. In both instances, the final learning outcome is achieved even though the learning journey taken to reach the final destination differs.

The next step is to expand the list of benefits in using critique sessions that have been developed for this current module to be implemented for the other modules in the same course. The final intention by the author will be to initiate further explorations that can effectively implement the critique techniques for other Diploma courses in Singapore Polytechnic.

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BIOGRAPHICAL INFORMATION

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EVALUATION OF SPIRAL CURRICULUM FOR CHEMICAL ENGINEERING USING CDIO FRAMEWORK

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ABSTRACT

This paper shares the experience of the Diploma in Chemical Engineering (DCHE) of Singapore Polytechnic (SP) in using the CDIO Framework to guide the design of spiral curriculum for chemical engineering students. In this spiral curriculum model, simple concepts are introduced to the students first, which are then revisited and re-construed in a more in-depth and elaborated manner throughout the three-year course. The CDIO learning outcomes are intertwine into the context of learning to support the levelling up of knowledge and skills from one semester to another, from one module to another, while integrating critical thinking skills with disciplinary knowledge to provide a more holistic approach to engineering education for our students. The paper first introduces spiral curriculum for chemical engineering and explains how the modules are sequenced within the three-year course based on the complexity of concepts, context of learning as well as opportunities for application and integration of knowledge. Then, it describes the use of block teaching as a means to deliver the spiral curriculum where knowledge and skill competencies are levelled up via a cluster of modules offered within a semester. DCHE had two runs of block teaching and the third run is currently in-effect. Qualitative and quantitative surveys were carried out to evaluate the effectiveness of block teaching on student learning and student performance in assessment across different cohort of students in the first two runs. A z-test was used to compare student academic performance at 5% significance level and statistically there are no significance difference. It was found that generally student were able to connect the concepts taught from one module to another better compared to a non-spiral curriculum. Some improvement plans had been implemented based on the feedback of the first two runs and these are discussed in the paper. Faculty teaching staff who facilitate the learning with students also plays an instrumental role in the spiral curriculum where they must have the ability to provide the integrated learning experiences to students and help students make connections between the concepts that are taught in different modules and across semesters. So, it is important that faculty members are able to deliver more than one subject or area of study. While there are benefits for using block teaching to aid student learning, there are challenges and trade-offs which are further discussed in the paper. In the last section of the paper, it outlines the broad areas where we strive to continue to study the effect of block teaching in future cohort of students to improve the delivery of the spiral curriculum and support student learning.

KEYWORDS

Chemical Engineering, Spiral Curriculum, Block Teaching, Standards: 3, 11, 12

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

INTRODUCTION

The Diploma in Chemical Engineering (DCHE) course from Singapore Polytechnic (SP) had adopted CDIO as the basis for revamping its curriculum since 2007 and its “CDIO-enabled” curriculum was introduced for the first time in April 2008 for students in the Academic Year 2008/2009 cohort (Cheah, 2009). There was a need to shift the curriculum model, which was largely content driven and taught in silos with little connectivity between modules, to one focusing on key concepts fundamental to understanding and in a more integrated format [Standard 3 – Integrated Curriculum]. In addition to integration of discipline-specific knowledge in the curriculum, various generic skills such as teamwork, communication and critical thinking were integrated into carefully designed learning activities in laboratory sessions or assignments to core chemical engineering modules.

Since then, several national initiatives such as Singapore Skills Framework and Industry 4.0 took off which led to further review of the course to re-design and deliver appropriate learning content to meet both existing and emerging skills required for the changing industry needs and work roles [Standard 12 – Program Evaluation]. The redesign of the chemical engineering curriculum and its CDIO experiences after years of implementation were documented in various earlier papers, e.g. Cheah, Phua & Ng (2013) and Cheah & Yang (2018).

As part of a continual improvement over past efforts, the most recent revamp of the DCHE course took place in 2017 which led to the adoption of the spiral curriculum model for its course structure for students in the Academic Year 2018/2019, in response to providing a more systematic structure to build up student competencies using the CDIO approach while ensuring the curriculum retains its integrated form.

The process undertaken by the Course Management Team to carry out the transition had been described by Cheah & Yang (2018). The DCHE curriculum model shown in Figure 1 illustrates the progressive development of key competencies over the diploma’s 3-year duration.

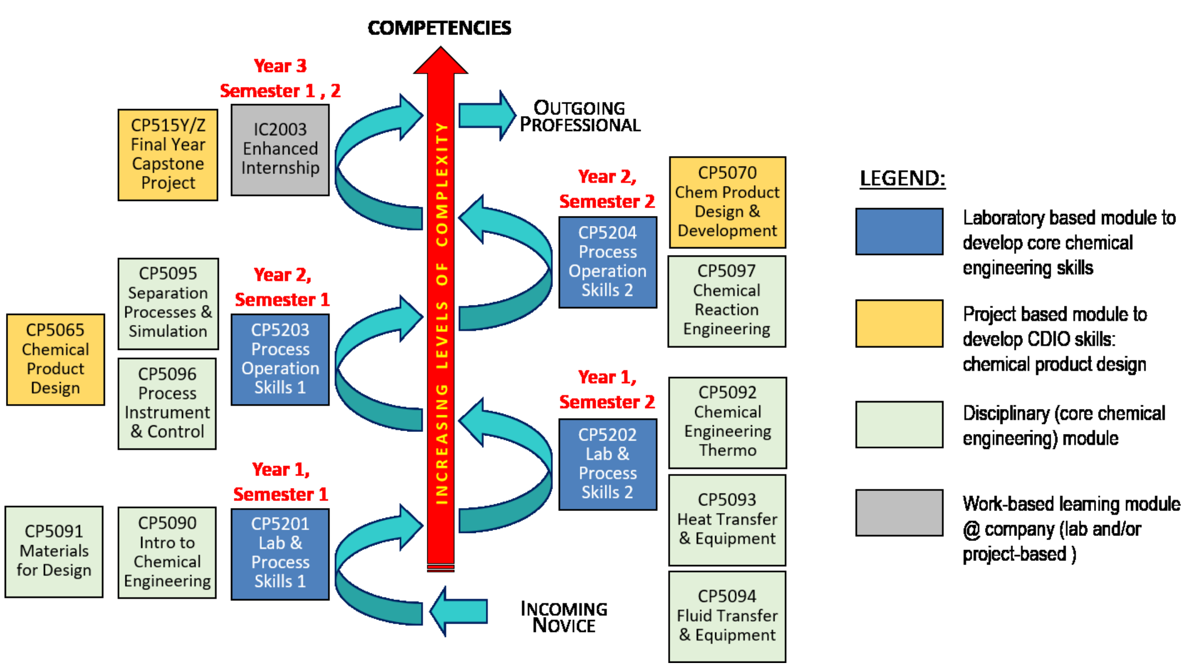

Figure 1. The DCHE Spiral Curriculum Model

One of the key changes in supporting the spiral curriculum is the way of teaching the core modules. More specifically, we implemented the practice of "block teaching" in which core modules are covered in a more compact manner, with greater contact hours per week but in lesser number of weeks; instead of over the entire semester (Cheah & Wong, 2019).

At the time when this paper is published, DCHE had two runs of block teaching which were in Academic Year 2018/2019 (first run) and Academic Year 2019/2020 (second run). The third run is currently in-effect. Hence, this paper presents the challenges faced in the implementation of block-teaching, improvements made to address the shortcomings, findings on students' perception of block teaching in terms of learning effectiveness and comparison of student performances across different cohorts as a result of the transition.

WHAT IS A SPIRAL CURRICULUM?

Spiral curriculum is a concept widely attributed by Bruner (1960), who refers to a curriculum design in which key concepts are presented repeatedly throughout the curriculum, but with deepening layers of complexity, or in different applications. Bruner (1960) believes that "a child of any age at any stage of development is capable of understanding complex information if the subject is effectively taught in some intellectually honest form", notably via a spiral curriculum. In another words, the information is structured so that complex ideas can be taught at a simplified level first, and then re-visited at more complex levels later on. Therefore, subjects would be taught at levels of gradually increasing difficultly – hence the spiral analogy. Such treatment allows the earlier introduction of concepts traditionally reserved for later, more specialized courses in the curriculum, after students have mastered some fundamental principles that are often very theoretical and likely to discourage students who are eager to apply the concepts they are learning to real-world applications.

The spiral model of learning is lauded by Sheppard et al. (2008) as "the ideal learning trajectory with all components revisited at increasing levels of sophistication and interconnection. Learning in one area supports learning in another." In such a model "…the traditional analysis, laboratory, and design components would be deeply interrelated: engineering knowledge remains central but is configured to include both technical and contextual knowledge; competencies of practice, laboratory, and design experiences are integrated into the whole, as are professionalism and ethics. The overarching goal of the program would be to position students for a lifetime of continuous learning and growth."

EFFECTIVENESS OF SPIRAL CURRICULUM IN ENGINEERING EDUCATION: WHERE IS THE EVIDENCE?

Applications of spiral curriculum have been reported in the literature centered around the teaching of mathematics (e.g., Cowan, et al., 1998; Singapore Ministry of Education, 2007), basic sciences (e.g. Grove et al., 2008) and in the field of medical education (e.g. Harden & Stamper, 1999; Brauer & Ferguson, 2015; Ovadia-Blechman et al., 2016).

Application of spiral curriculum in engineering education had been reported by Collura et al. (2004) for multi-disciplinary engineering program, Gomes et al. (2006) and Gupta et al. (2008) for undergraduate chemical engineering degree courses and Neumann et al. (2017) for chemical engineering master degree program.

Fraser et al. (2019), in a study comparing spiral and traditional curriculum in preparing medical students to diagnose and manage concussions, noted that the spiral curriculum promotes a strong understanding and retention of knowledge. Likewise, Gomes et al. (2006) and Gupta et al. (2008) believe that spiral curriculum is a superior learning approach because it allows students to "master each increment of subject in hierarchical sequence before going on to the next" (Gupta et al., 2008). In fact, Gomes et al. (2006)'s study reveals that there is significant increase in student engagement within the broader learning process. Masters & Gibbs (2007) finds the spiral curriculum to be very effective for online learning if the practice is used consistently.

Herrick et al. (2003) reported on the use of spiral curriculum to optimize the students' learning process and retention rates of students in electrical engineering. Similarly, the trends reported in Gomes et al. (2006) and Gupta et al. (2008) studies suggest that curriculum reform and implementation of the spiral curriculum lead to "valuable gains" in chemical engineering degree programs (Gupta et al., 2008), enhance student motivation and self-directed learning (Gomes et al., 2006). Moreover, there are meaningful improvements in retention rates, graduation rates and student performance in general after applying spiral curriculum principles (Neumann et al., 2017).

DiBiasio et al. (1999) reported on their work in chemical engineering, noting that the spiral curriculum has improved students' learning of technical content, teamwork and communication skills as well as their identification with chemical engineering as a major and a profession. The technical proficiency of the students from the experimental group (i.e. using taught spiral curriculum) is at least equal to that of traditionally taught students, while their attitudes toward chemical engineering and towards the value of teamwork are considerably more positive than those of traditionally-taught students.

Noting that many applications of spiral curriculum have shown positive effect on student learning, including DCHE, there are various challenges in its implementation, which are further elaborated in this paper.

BLOCK TEACHNG IN DCHE

Block teaching is used as a means to deliver the spiral curriculum in DCHE course where one module is sequence one followed by another. It was first rolled out in Academic Year 2018/2019 in which students started the semester with *Chemical Engineering Thermodynamics (CP5092)* module, followed by *Heat Transfer & Equipment (CP5093)* and *Fluid Flow & Equipment (CP5094)* modules. The block teaching schedule is illustrated in Figure 2, where the semester consists of 18 weeks inclusive of 3 weeks of mid-semester vacation (Week #9 to #11).

With reference to Figure 2, the module content of *Chemical Engineering Thermodynamics* was the first module to be covered in the semester and a test was administered on Week #3 where about 50% of the module content had been covered. The purpose of the test is to allow faculty members to gauge student learning. The examination was scheduled at the end of the semester as a summative assessment for the module. As the module was categorised as an examinable module in Academic Year 2018/2019, based on the institutional requirement, the examination could only be held at the end of the semester which is either on Week #19 or Week #20. To ensure that students stay connected with the module, a one-hour lesson was crafted out in each week from Week #12 to Week #17 to provide revision and prepare the students for the examination.

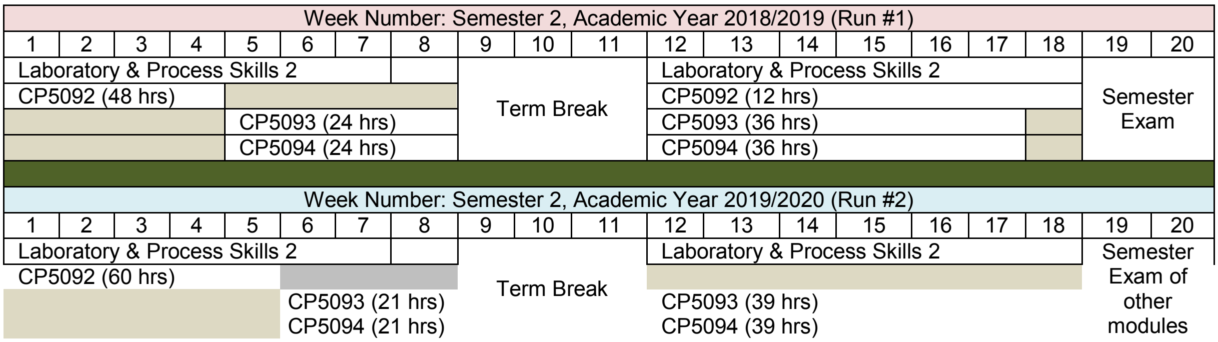

Figure 2. Schedule of Block Teaching in Academic Year 2018/2019 (Run #1) & Academic Year 2019/2020 (Run #2)

Leveraging on the concepts covered in *Chemical Engineering Thermodynamics*, in particular, the 1st Law of Thermodynamics, the remaining two modules, *Heat Transfer & Equipment* and *Fluid Flow & Equipment* were taught in parallel. These two modules focus on the application of 1st Law of Thermodynamics in different context which allowed students to build on the fundamental concept and develop understanding in higher complexity. This systematic approach resulted in an integrated curriculum that involves linking a core module with key concepts from other core modules while integrating critical thinking skills. Hence, an integrated test for *Heat Transfer & Equipment* & *Fluid Flow & Equipment* modules was administered in week #14 to evaluate the application of knowledge from both modules. A scenario-based approach and various pedagogies were used to design the assessment questions where scenarios reflecting possible real-world work tasks or environments provide the context for students to utilise their prior knowledge when appropriate and demonstrate knowledge transfer from one module to another (Cheah, 2009). The survey results discussed at later part of this paper also showed that students were able to integrate the knowledge learnt.

EFFECT OF BLOCK TEACHNG ON STUDENT PERFORMANCE

The Course Management Team examined the impact of block teaching on student performance. So, the academic performance of the students in the first run of block teaching (students from Academic Year 2018/2019) was compared to an earlier cohort (students from Academic Year 2017/2018) without block teaching. The z-test is used to compare the mean score of the cohort with and without bock teaching at 5 % significance level using the data in Table 1.

It was found that the performance of students are comparable with no significance difference in the key performance index (mean score and pass rate) at 5% significance level for all three modules. Pass rates have been consistent with and without block teaching. This means that even when the modules are covered in a more compact manner, the students achieved similar academic performance as compared to modules covered over the entire semester.

After the first run of block teaching, some improvements were made to the block teaching schedule. The academic performance of the students of Academic Year 2019/2020 (second cohort with block teaching) was compared with students of Academic Year 2018/2019 (first cohort with block teaching) and 2017/2018 (the cohort without block teaching), which are also summarised in Table 1. Once again, the performance of students are comparable with no significance difference in the key performance index (mean score and pass rate) at 5% significance level. Pass rates have been consistent with and without block teaching. This means that student academic performance is independent of the duration used to cover module content.

Table 1. Comparison of Key Performance Index with and without Block Teaching in Academic Year 2018/2019 (run 1) & Academic Year 2019/2020 (run 2)

	CP5092 Chemical Engineering Thermodynamics			CP5093 Heat Transfer & Equipment			CP5094 Fluid Flow & Equipment		
Curriculum	Non-block	Block Run 1	Block Run 2	Non-block	Block Run 1	Block Run 2	Non-block	Block Run 1	Block Run 2
Mean Score	71	69	71	74	75	68.4	72	74	75
Pass Rate	99.3%	98.4%	96.1%	99.2%	98.4%	97.6%	98.4%	100.0%	97.6%

SURVEY RESULTS ON BLOCK TEACHING

The Course Management Team has vested interest to understand students' perception on the block teaching model. Hence, a quantitative survey was conducted at the end of each semester. Specifically, students were asked to indicate on a 5-point Likert scale the extent to which they agree or disagree with the following statements with 1 being Strongly Disagree and 5 being Strongly Agree.

Question 1: With the block teaching format, I was able to see connections between what was taught in the 3 different modules

Question 2: The block teaching format enables me to better understand the basic engineering concepts

Question 3: The block teaching format challenges me to think in depth (e.g. analyse, compare and contrast, evaluate)

Question 4: The block teaching format reduces the amount of varied information to deal with at any one point in time and hence increases my ability to focus attention on specific topics

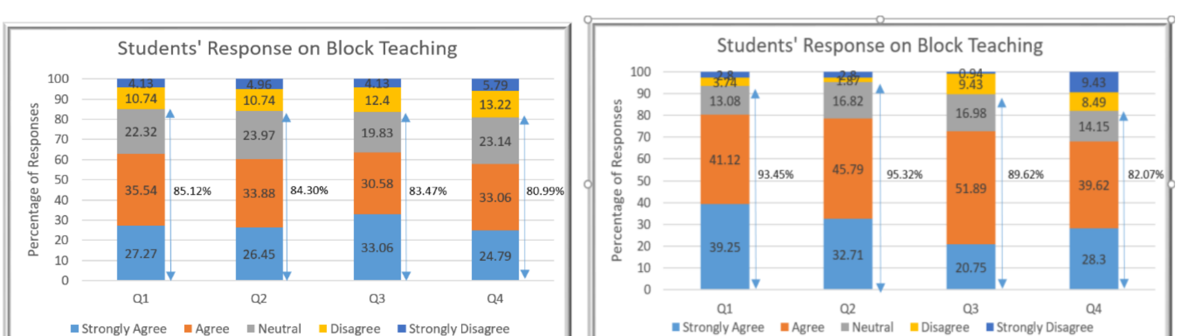

Figure 3. Students' Responses on Block Teaching in Academic Year 2018/2019 (left) and Academic Year 2019/2020 (right)

Figure 3 (left) shows the response obtained from the first cohort of block teaching with a response rate of 89.6%. Based on the responses obtained, 85.12% of the students agreed that they are able to "see the connections" among the three modules where block teaching enhances students' ability to integrate knowledge learnt and strengthen their ability to solve problem of higher level of complexity. In another words, the integrated curriculum had enabled students to link the key concepts from one core module to other core modules.

84.30% of the students agreed that the block teaching format enables them to better understand the basic engineering concepts and 83.47% of the students agreed that the block teaching format challenges them to use higher order thinking skills. This enabled students to build on key concepts at the beginning of the semester and complex concepts are then developed more elaborately throughout the semester in different context whereby students develop critical thinking skills within the chemical engineering context.

80.99% of the students agreed that block teaching format reduces the amount of varied information to deal with at any one point in time. This allowed them to focus their attention on specific topics, activate prior knowledge and carry the knowledge one step higher to a new level of comprehensiveness. This may have attributed to students performing equally good even though the modules are covered in a more compact manner.

In summary, the quantitative survey result obtained from the first run of block teaching was encouraging with majority of the students either "Agree" or "Strongly Agree", indicating strong alignment to the intended outcome.

In addition to the quantitative survey described above, a qualitative survey was also carried out using the following questions.

Question 5: What **difficulties** (if any) did you experience with the block teaching format?
Question 6: What **positive** aspects did you experience with the block teaching format?

The main issue students faced in the first run of the block teaching was the schedule of Test 1 for *Chemical Engineering Thermodynamics* [Standard 11 – Learning Assessment]. Hardly had they accustomed to the new semester, they had to take the test in Week #3. Another concern was the schedule of the module's examination, which was held almost three months after the syllabus was covered, making the process of revision challenging. Some felt that the schedule is too intense for the first module.

To address these issues surfaced from the survey, the module team identified two areas for improvement. Firstly, adjustment was made in the teaching schedule and implemented in Academic Year 2019/2020 (second run of block teaching) as shown in Figure 2.

When Test 1 of *Chemical Engineering Thermodynamics* was scheduled on Week #4 instead of Week #3, this gave students an additional week for preparation. The module content was covered within a duration of five weeks. This was an increase of one week from the previous run of four weeks. This allowed the module content to be delivered at a slower pace that allows the students to grasp what is being taught, manage new information, translate them into useful knowledge and stay engaged.

Secondly, the modules were changed from examinable to non-examinable type. The summative assessment at the end of the module was renamed from examination to Test 2 while maintaining the rigour of the assessment. This provided the module team the liberty to schedule the test at an appropriate time during the semester. So, Test 2 of *Chemical Engineering Thermodynamics* was scheduled a few weeks after the module content had been taught to avoid a long time lapse between the completion of the module and the date of the summative assessment. The test was also scheduled on the week after the mid-semester vacation where students could use the vacation time to revise the learning material.

After the improvements were implemented for the second run of block teaching, the same quantitative and qualitative survey questionnaire was carried out to evaluate the impact of the revised implementation. The result is shown in Figure 3 (right) with a response rate of 87.9%. The responses received shows a remarkable improvement as compared to that of the first run. The percentage of "Agree" and "Strongly Agree" responses increased with an average of 13.6% based on the four questions. The revised schedule provides students with a more balance workload throughout the semester and, hence, enable them to have a better grasp of fundamental concepts. This is evident where students find the block teaching format to be "very enriching, a lot of topics taught are interlinked, and it made me apply the previous chapters more efficiently". One of the students also responded that "I felt that it was useful as it opened my eyes to how to integrate concepts from different modules together."

In summary, the block teaching format leverages on prior knowledge to enable students to step higher to a new level of rigour. This approach requires students to utilise and activate prior knowledge thereby strengthening the grasp of fundamentals before learning at a deeper level. Such reinforcements increase the students' confidence and ability in solving authentic but usually complex problems.

FACULTY TEACHING COMPETENCE

Faculty members play a pivotal role in the success of the block teaching format. The improvement could be attributed to the fact that with more experience after the first run, faculty members in the module team have greater capability to effectively impart the fundamental engineering concepts in the first module and reinforce the concepts in the subsequent two modules, thereby assisted the students to connect the dots among the concepts.

To design a curriculum that is cohesive, the block teaching approach requires faculty members to collaborate and coordinate on the content to be taught across different modules, when and in which modules and at what level of complexity. Faculty members will have a good overall concept of the curriculum instead of teaching in silo that translates to higher proficiency in creating the links for students within a module and between different modules. They play an active role in explaining explicitly how the key concepts are linked from one module to another, thus providing an integrated learning experience to students. Students were motivated to learn when the faculty member presents the process and content well (Hazel Mae & Alegre, 2019). So, faculty members must have the competence to deliver technical content that spans across different areas of studies in chemical engineering, which is different from traditional practice.

In order to achieve a coherent teaching practice across the entire cohort of students, the module team leader designs the teaching and learning materials using the CDIO approach described by Cheah (2009) using case studies and various pedagogies. At the beginning of each semester, the module team leader conducts a briefing to the module team members so as to ensure everyone in the teaching team aligns to the learning outcomes and delivers an integrated learning experience to students. As the module team typically consists of more than three faculty members, delivering consistent integrated learning experience for the entire cohort of students is highly desirable but a real implementation challenge. Nonetheless, the Course Management Team encourages faculty members to maintain the openness to seek clarification and share best practices as they place students' best interests at heart.

Finally, when a faculty member teaches the same group of students across various modules in the block teaching model, this typically results in greater rapport formed between students and faculty members, which can serve as an indirect inspiration for students to perform well.

PLANS FOR MOVING FORWARD

The outcome of this study was based on the modules offered within a semester of a three-year course. Some feedback were gathered from the first cohort of students through a focus group discussion when they progressed to later years in the course. These anecdotal evidences also suggested that:

1. Interaction between lecturer and student reinforces integrated learning.
2. Block teaching provides "levelling up" for students.
3. Block teaching helps students focus on their learning.

The Course Management Team will continue to gather more tangible evidences that illustrate students deepening their understanding in the spiral curriculum, seeing relation and connection between concepts, especially in later years of studies. The team will also review the integration of critical thinking in the curriculum where Sale & Cheah (2013) described the teaching and application of critical thinking in Year 3 curriculum. However, the development of critical thinking can be facilitated through a variety of active learning strategies that systematically cue such types of thinking. So, there are opportunities for this to be taught starting in Year 1, subsequently be enhanced in Year 2 and applied in Year 3.

Survey responses indicated that block teaching and spiral curriculum benefitted students, however, there are operational challenges such as scheduling tests and managing assessment workload. These remain to be optimised by distributing the workload throughout the semester so that it is more manageable for the students so as to making learning more conducive. For example, when the final summative assessment of *Chemical Engineering Thermodynamics* was scheduled after the mid-semester vacation, some students felt that they were deprived of a proper vacation break where they had to use their vacation period to do revision and preparation for the final test. So, in Academic Year 2020/2021 (third run of block teaching), the final test will be scheduled before the vacation period so that the students do not need to do revision during mid-semester vacation. This will give students a well-deserved rest time.

In addition, to help students "gear up" after a 6-week long vacation between semesters, a Back-to-Campus activity will be introduced on the first week of Semester 2. It aims to enable students to kick start the semester effectively. The activity requires students to activate prior knowledge acquired in Semester 1 and apply it in a given scenario to solve some engineering problems. The activity provides the platform for students to activate prior knowledge and integrate the concepts learnt in Semester 1 and provides a preview of important concepts to be introduced in Semester 2. This will further enhance the spiral curriculum structure.

Lastly, this study has shown that the student performance are comparable with no significance difference in terms of mean score and pass rate. Other interacting factors could have been present but not discussed, such as student's pre-diploma educational background, learning ability, mode of lesson delivery and students' perceptions on the use of CDIO approach. These can be further investigated in future studies and build upon the current efforts to improve student performance.

CONCLUSION

In conclusion, the spiral curriculum model has benefitted student learning where key concepts and principles are revisited over time to further clarify and extend the knowledge base. This is achieved by adding new related knowledge, enhancing knowledge and skills integration and further refining them until students make sense and apply them purposefully and meaningfully. Faculty members play vital roles in teaching key concepts that are fundamental to understanding, and the need for spaced deliberate practice over time to ensure that knowledge and skills are encoded and cemented in the student's long term memory. The implementation of spiral curriculum using block teaching as a means for the DCHE curriculum has shown positive impact on student learning where suitable pedagogy arrangements are applied and supported by faculty members to facilitate learning that is of most worth to the students.

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CDIO APPROACH IN DEVELOPING SOLUTION MINDED LEARNERS

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ABSTRACT

From its early days as the first polytechnic in Singapore, Singapore Polytechnic (SP) has been working closely with the government to train and arm the workforce with the skills needed for the country's economic growth. As the pace of globalisation accelerated in the 80s to 90s, the strategic policy was implemented to strengthen and drive towards becoming an innovation economy. This strategy led to the setting up of research and innovation centres in the local Institutes of Higher Learning (IHL) such as SP. In SP, the Civil Engineering course is one of the first engineering courses that offers a broad-based engineering discipline. The School of Architecture and the Built Environment (ABE) is the first school to offer built environment related courses, including the civil engineering course, before being a coordinator of training for the Building and Construction sector among the five local polytechnics. As an applied learning institution, ABE Civil Engineering has adopted the CDIO approach allowing staff and students to engage in real-life and industry relevant research projects to enable the application of knowledge and the use of CDIO skills to conceptualize, design and develop industry relevant solutions. Such engagement in real-life and industry research project settings enable students in their final year projects (FYP) to directly contribute to real-life such industry projects, while building their proficiency to become solution-minded learners who are both innovative and have a curious mindset.This paper describes the integrated learning process of how the adoption of CDIO approach can be realised with staff in close collaboration with the industry to pursue industry relevant solutions. This integrated learning experience (CDIO Standard 7) can foster the learning of disciplinary knowledge simultaneously with solution-minded strategies.This collaboration with the industry explores the journey that ABE has taken from concept, design to development of its green masterplan, to its evolution and establishment of focus on green technology research that expose students to such research areas through their (FYP) involvement. Two research projects of recycling of palm frond into bioplastic, and also of incinerator ash to aerogel materials, will be utilised to show how these FYP student activities help students to be solution-minded in their approaches. Feedbacks were collected through face-to-face interviews with the two groups of students to identify challenges and propose improvements to facilitate the integrated learning experiences. This paper represents the work of the current CDIO implementation and the initial development of a new module.

KEYWORDS

Solution minded, green technology, industry projects, curious mindset, innovative, Standards: 2, 3, 7

INTRODUCTION

Circular Economy has become an economic imperative more than ever, compounded with many pressing factors such as game-changing and world-changing phenomena that have changed the industrial landscape. Among these factors, Industry 4.0 revolution, environmental/resource impact, social and regulatory pressures (Lopes de Sousa Jabbour *et al.*, 2018). There is only so much of resources at human's disposal in the current stage, making a paradigm shift from linear to circular the sustainable way to reconcile with the nature (Michelinia, 2017). This far-reaching trend has resulted in many countries, including Singapore, setting zero-waste masterplan as one of its key priorities (NEA, 2020). This paper explores the green journey that the institution, Singapore Polytechnic, has taken from concept, design to development of its green masterplan to its evolution and establishment of focus on the development of the civil engineering education with green technology infusion.

BACKGROUND: EVOLUTION IN SUSTAINABLE RESEARCH INITIATIVE

Singapore Polytechnic have had a deep root of green concept from early days of the establishment. It has been embodied in the institution's green pledge and exemplified in its campus in a garden philosophy (Singapore Polytechnic, 2014). The culture had permeated to its teaching, learning and research with the key green technologies development activities taking place in its various schools, such as the waste recycling process technology developed jointly by the School of Architecture and the Built Environment (ABE) and the department for technology, innovation and enterprise (TIE).

From its early days as the first polytechnic in Singapore, it has been working closely with the government to train and arm the workforce with the skills needed for the country's economic growth. As the pace of globalisation accelerated in the 80s to 90s, the strategic policy was implemented to strengthen and drive towards becoming an innovation economy (Strait Times, 2017). It was with this strategy that led to the setting up of research and innovation centres in the local Institutes of Higher Learning (IHL) such as Singapore Polytechnic.

With the launch of the government's zero-waste nation vision and setting the year 2019 as the Year towards Zero Waste, the momentum was accelerated for the institution to consolidate the green technologies and charting its course for specific thematic technology research to build up its technological edge.

Building Platforms for Research Scale-up

School of Architecture and the Built Environment (ABE) was the one of the oldest schools in the institution that at one point offered degree courses in 1965, before the decision to transfer the faculties of architecture and engineering to the University of Singapore in 1968. It was of no coincidence that the ABE as the first school to offer BE related course (Singapore Polytechnic, 2018) was appointed as the sector coordinator for Building and Construction among the local polytechnics (MOE, 2016).

Apart from its extensive lesson-based pedagogy, as an applied learning institution, ABE has been through its practical learning platform allowing staff and students to engage in real-life and industry relevant research projects to enable the application of knowledge and the use of skills to conceptualise, design and develop industry relevant solutions. These efforts have paid off well with its projects winning awards for several years in the Greenwave competitions

(Sembcorp, 2015). Imbued with passions to pursue industry relevant solutions for augmenting academic excellence, the ABE school's close collaboration with the AMTC transformed the research ecosystem in the institution into a powerful twin-engine, which allows both the industry-relevant applied pedagogy and the applied scientific research's calibrated integration for allowing the development of an innovative and curious mindset in its solution-minded graduates (Singapore Polytechnic, 2015). Such kind of industry-research-infused methodology plays an instrumental role, among other strategic initiatives in achieving its mission of "Life-ready, Work-ready and World-ready".

With a school and TIE coming together, working on a calibrated approach, such collaborative platform allows for the systematic way of training of both staff and students through a structured framework that encompasses different work packages designed for supporting the industry. The work package's themes are aggregated from the industry, representing the problem statements that requires innovative solutions to either to increase the productivity or the development of specific capability to uplift the industry. In this way, not only does the industry benefit through the skilled and entrepreneurial workforce, such kind of industry engagement with companies offers them the opportunity to transform their business with solutions designed to increase their competitiveness. The application of aerogel to multiple areas in BE materials was achieved for the waste to aerogel project through such platform (Strait Times, 2019).

Manifesting People- Private- Public Partneship Spirit

In Singapore, the relationship is manifested in a People-Private-Public (3Ps) Partnership as first defined by the Singapore 21 Committee (1999). The 3P partnership elevates the scale of collaboration allowing for a multiplier effect on the technology solutions developed by the institution to be proliferated at a quicker pace and to a broader range of target audience. In the waste to aerogel project for example, the partnership with the waste recycling association has yielded successful training and industry projects (Teo, 2018). To close the waste loop, the cooperation and interwoven working network of the waste producer and waste recycler is critical for the business case to work in the circular economy. As such, identifying the right partner to work with from the proof of concept to proof of value and ultimately an industry pilot scale-up is important. Therefore, through the institution's technology development strategy of a "Seed", "Grow" and "Scale" phase of staging technology development projects, there is always an industrial collaborator involvement. While the seeding phase sees primarily laboratory experimental type of projects, most industrial collaborators will generally be more willing to take part in the "Grow" and "Scale" phase where the project is of a certain level of technology readiness level and the commercial potential is more apparent.

CDIO Approach In Developing Solution Minder Learners

Problem solving skill is the most in demand in the workplace. This is reported in an Economist Intelligence Unit report (2015): Preparing students for the future, sponsored by Google for Education. We believe that solution minded is a mindset that focus on solutions and is an essential driver of problem solving. Jenkins and Germaine (2018) have shown that solution-oriented learning helps students to stay positive. It is important to understand that being focused on solutions does not mean that we are denying the existence of a problem but rather it is by identifying a problem or a challenge that leads our step to move forward to the solution.

To support students to become a solution minded learner, the kind of mental activities that leads to this mindset thinking has to be made visible in their learning process. CDIO approach is adopted to make this thinking visible.

CDIO emphasizes on an approach to strengthen the learning of the fundamentals and at the same time improves the learning of personal, interpersonal skills and product, process and system building skills through experiential learning set in the context of conceiving-designing-implementing-operating (CDIO) team-based environment (Crawley *et al.*, 2007). An integrated syllabus is also crucial in building a structure so that a student can easily grasp it, also supported by Bruner (1965) who has a significant impact on education and on the understanding of the learning process (Donaldson, 1978).

Civil Engineering (CE) course, a 3-year programme in ABE, is a broad-based engineering discipline, which focuses on developing students' competencies in solving problems in the society while maintaining positive attitude in learning. In recent years, there is an increase need for civil engineering diploma graduates who have an open mindset and interest in involvement in tackling sustainability issues.

The Integrated Learning Process

To equip students with solution minded thinking skills, various problem-solving tools or approaches were contextualized into the CDIO stages. Table 1 outlines tools and approaches integrated into CDIO stages in the CE course 3 years' programme.

Disciplinary subjects are mutually supporting when they make explicit connections among related and supporting content and learning outcomes. An explicit plan identifies ways in which the integration of CDIO skills and multidisciplinary connections are to be made.

Figure 1 shows a diagram illustrating a CBL project spine with some supporting modules in the DCEB course and finally a final year project with all supporting modules in year 1, 2 and 3.

Table 1. Problem Solving Tools or Approaches Contextualized into CDIO

CDIO Stages				**CE Course**	**Problem Solving Tools / Approaches**			
					Strategies for Question Generating and CBL	Problem solving tools (e.g. Ishikawa Diagram and Scamper)	Design Thinking	Self-Directed Learning (SDL) Strategies
C	D	I	O					
√		√		Year 1	√		√	√
√	√			Year 2		√	√	√
√	√	√	√	Year 3*				√

** Students in CE course do their FYP and Internship in year 3*

Details of the project spine in DCEB course described as follows:

- Year 1- Introduction to Civil Engineering module. A project of making a high-rise framework using wooden sticks in line with learning basic structure theory.
- Year 2- Water Technology module. Use of CDIO approach to design HDB rooftop rainwater harvesting system in a mini project. A checklist is provided as guiding questions.

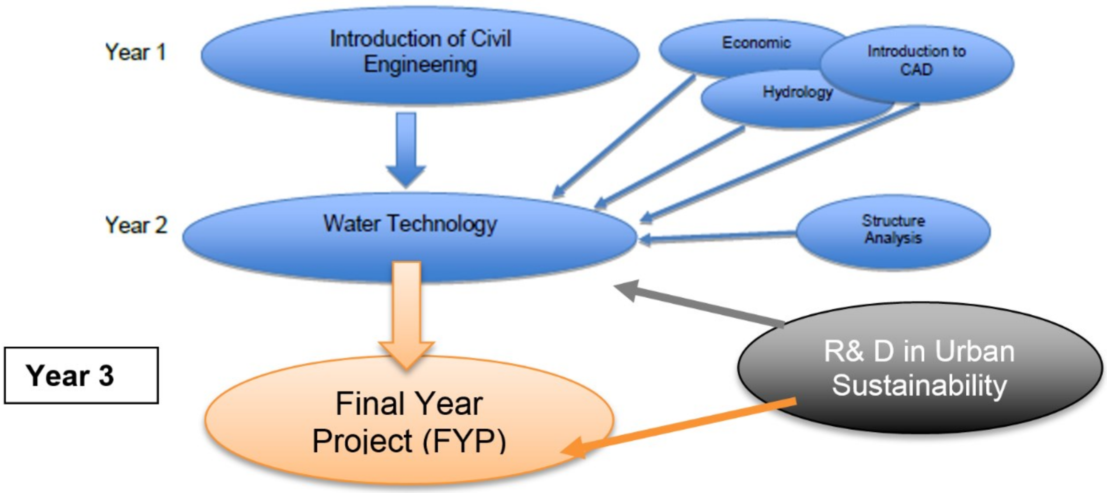


Figure 1. CBL implementation into DCEB

In the 2nd Year, a mini project that incorporates some 1st year modules such as Introduction to Civil Engineering, CAD design, Hydraulics & Hydrology and Economic was developed. In this particular study, a 2nd Year module entitled Water Technology was selected as one of DCEB course modules, environmental engineering sub-discipline. The module covered a mini CBL project with a theme of HDB rainwater harvesting project.

In a nutshell, a Challenge- Based- Learning (CBL) project is adopted to provide students with a collaborative learning experience working to solve real-world workplace issues, particularly in Singapore context. Results analysis and feedback of this implementation were presented at the Proceedings of the CDIO Asian Regional Meeting, Mongolian University of Science and Technology, Ulaanbaatar, Mongolia September 22 – 25, 2020 (Djati Utomo, 2020).

In the 3rd Year, problem solving tools, Challenge Based Learning (CBL) reinforced with industry sponsorships is adopted to provide students with a collaborative learning experience working to solve real-world workplace issues. Through deliberated practices guided by the SDL strategies throughout their 3 years of learning as shown in Figure 2, students were also expected to apply their learning across different contexts in their FYP and to further develop soft skills in the area of self-directed learning, teamwork, creativity, project management and global mindset.

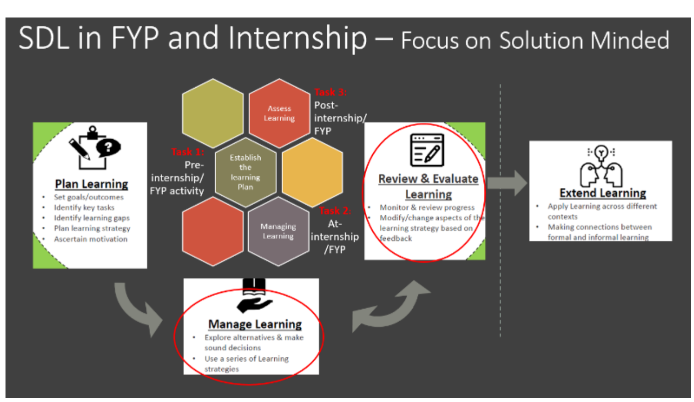


Figure 2. SDL – Focus on Solution Minded

Two FYP industry sponsored research group of recycling of palm frond into bioplastic, and another group of incinerator ash to aerogel materials were selected to continue the solution-minded journey with a teaching staff in close collaboration with the industry to pursue industry relevant solutions. Such engagement in real-life and industry research project settings has provided students the best learning environment leading them to be solution minded.

One of the FYP group has proven their contribution in a competition and awarded double prizes of SWIM (Sembcorp Innovation Medal) and the 1st runner up in SG Junior Water Prize Competition. As a result, attracted a small medium enterprise (SME) to sponsor their FYP in 2020.

STUDENTS FEEDBACK

To identify challenges and propose improvements to facilitate the integrated learning experiences, group instructional feedback technique was employed to collect feedback through face-to-face interviews with the two groups of students (8 students in total but 1 absent with apologies). Interviewees from these 2 FYP groups are students have done well in their 3 years' coursework with GPA above average.

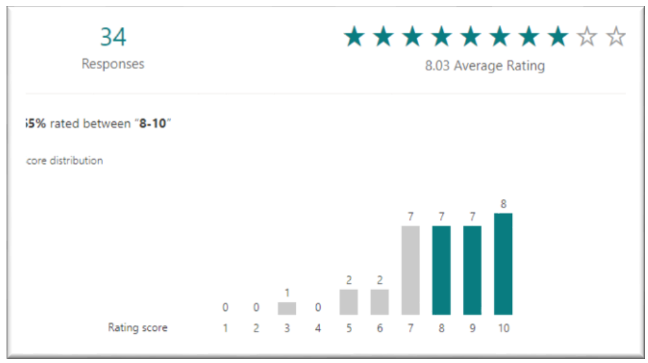
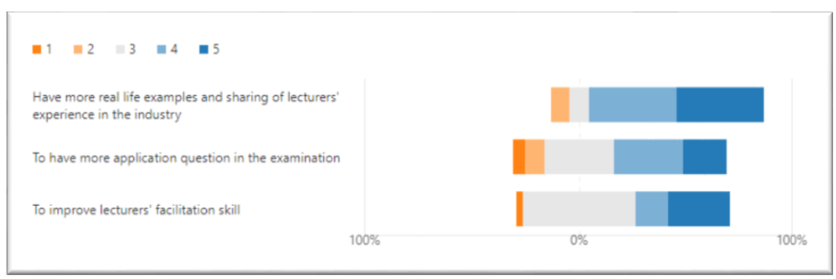
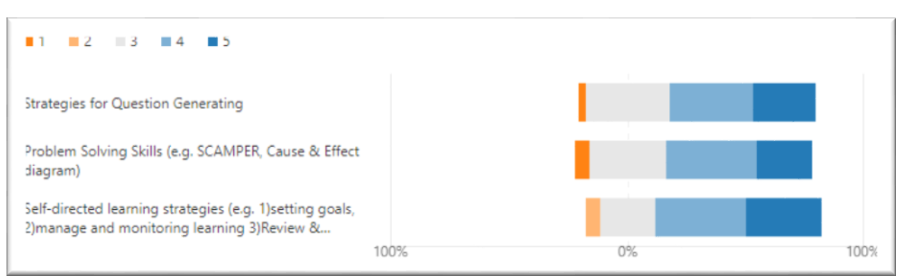
Interview was conducted at the end of their FYP. As students were not explicitly told that they were on a solution-minded learning journey during their course, proper facilitation is necessary before the interview. They were briefed on the definition of solution minded and to reflect on their learning journey leading them to be a solution minded learner in their 3 years course of study. They were then asked to fill out the following questionnaires and their responses are summarized in Table 2.

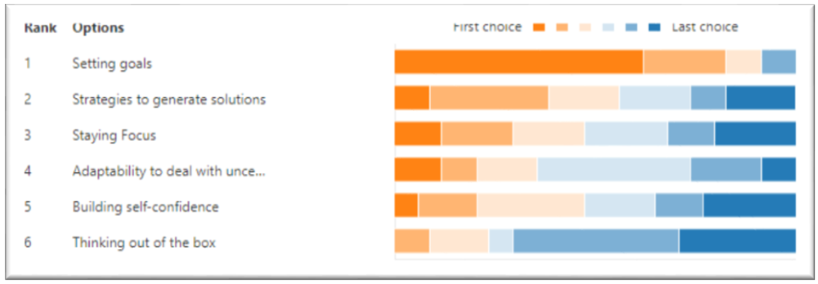
Table 2. Group Instructional Feedback from 2 FYP Research Groups

Interview Questionnaires	Summarized Response
1. What does the lecturer(s) do that help with your learning to be a solution-minded learner?	Lecturers are generally approachable and activities designed are appropriate with deliberate practices leading them to be solution minded learner.
2. What changes/improvements to the course would promote your learning to be a solution-minded learner?	Request for: • more real-life examples and sharing of lecturers' experiences in the industry. • more application question in examination • to improve lecturers' facilitation skill
3. What do you do that facilitates your learning to be a solution-minded learner?	Many Students have exhibited self-directed learners' dispositions. However, not able to articulate well specific problem-solving tools or strategies.
4. What might you do to improve your learning to be a solution-minded learner?	
5. What is the hardest thing to learn in the journey of a solution-minded learner?	Following key words are identified as the hardest : • Setting goals • Adaptability to deal with uncertainties • Strategies to generate solutions • Staying Focus • Thinking out of the box • Building self-confidence

Peers' ratings of questionnaire formulated based on the input from the F2F interview responses listed in Table 3 is used to collect data to quantify the identified challenges and improvements. 34 final year students participated. Survey was facilitated by first to brief them on the definition of solution minded and to reflect on their solution-minded learning in their 3 years course of study. They were then asked to complete the survey before their responses summarized in Table 3 below.

Table 3. Group Instructional Feedback from 2 FYP Research Groups

	Questionnaire	Results
1	Generally, lecturers are approachable and learning activities designed are appropriate to lead me to solution-minded.	(Rating are indicated by number of stars where maximum of 10 stars represent lecturers are approachable and learning activities are well designed. More than 65% has rated between 8-10 stars. 
2	Rate the following changes/improvements that would promote your learning to be a solution-minded learner. • Have more real-life examples and sharing of lecturers' experience in the industry • To have more application question in the examination • To improve lecturers' facilitation skill	(Rating scale : 1-Disagree 2- Slightly disagree 3-Neutral 4-Slightly Agree 5-Agree) 82% wanted to hear more real-life examples from lecturers 53% agree that by having more application question would help 44% agree that an improvement in facilitation skills would help 
3	Rate the following dispositions/skillsets that will facilitate/ improve your learning to be solution-minded. • Strategies for Question Generating • Problem Solving Skills (e.g., SCAMPER, Cause & Effect diagram) • Self-directed learning strategies (e.g., 1)setting goals, 2)manage and monitoring learning 3)Review & evaluate learning)	(Rating scale : 1-Disagree 2- Slightly disagree 3-Neutral 4-Slightly Agree 5-Agree) 60% rated 4-5 believed that these dispositions and skillets is important in leading them to be solution minded learners. 

4	Rate the following dispositions/skillsets from the Easiest to the Hardest to achieve. • Setting goals • Strategies to generate solutions. • Staying Focus • Adaptability to deal with uncertainties. • Staying Focus • Thinking out of the box • Building self-confidence	(Rating scale : 1- Easiest to 5 - Hardest) Majority have rated Adaptability to deal with uncertainity (65%) and Thinking out of the box (70%) as the most difficult to achieve. 

NEXT STEP: DEVELOPMENT INTO A CURRICULUM

A CDIO curriculum includes learning experiences that lead to the acquisition of personal, interpersonal, and product and system building skills, integrated with the learning of disciplinary content. Disciplinary subjects are mutually supporting when they make explicit connections among related and supporting content and learning outcomes. An explicit plan identifies ways in which the integration of CDIO skills and multidisciplinary connections are to be made.

Feedback in Table 2 & 3 showed that students have gained personal, interpersonal and appropriate disciplinary content and skills through the curriculum but lack of the connection to extended learning as seen in their response to the last questionnaire in Table 2. This is quantified by 34 participants' feedback and narrowed down to improve 2 important disposition/skillsets. To address this, ABE is planning to develop a module called R& D in Urban Sustainability the AY2021. The module aims to introduce students the basic research design principles and various data collection and analysis methods commonly used in science and engineering, and to equip students the knowledge of innovative and sustainable building materials and latest civil engineering (CE) technologies as well as giving them opportunities to practice thinking out of the box. The module will reinforce their solution-minded journey and to prepare them for the final year project and working in R&D related companies or lab testing companies. It will also develop students' competency in thinking skills, problem solving skills and interpersonal skills like teamwork and communications.

This module is conducted through a combination of lectures, tutorials and practical. Lab testing skills of advanced materials in civil engineering will be covered in the module. Students are expected to participate in workshops, seminars and technical conferences as part of the module requirements. Guest research scientists/ lecturers may be invited to present talks on the latest development in civil engineering. Students will be introduced to a wide range of literatures and case studies will be discussed in the module.

The students formed teams and worked together to define learning goals as well as negotiate within team members to set project timelines. The lecturer shall play the role as an advisor to guide students in managing and monitoring their learning progress.

CONCLUSION

An integrated curriculum in a CDIO approach has allowed staff and students to engage in real-life and industry relevant research projects to enable the application of knowledge and the use of CDIO skills to conceptualize, design and develop industry relevant solutions. Such engagement in real-life and industry research project settings enable students in their final year projects (FYP) to directly contribute to real-life such industry projects, while building their proficiency to become solution-minded learners who are both innovative and have a curious mindset.

This integrated learning process can be further realized with staff in close collaboration with the industry to pursue industry relevant solutions. This integrated learning experience (CDIO Standard 7) can foster the learning of disciplinary knowledge simultaneously with solution-minded strategies. This is clearly seen in the 2 FYP groups working on industry project facilitated by the teaching staff in close collaboration with the industry partner. The 2 FYP groups' feedback, together with 34 other students have allowed us to identify challenges faced by learners in the solution-minded learning journey.

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BIOGRAPHICAL INFORMATION

Handojo Djati Utomo is currently as a Civil Engineering Lecturer, R& D Unit of Civil Engineering, School of Architecture and The Built Environment (ABE) at Singapore Polytechnic, Singapore. He received a PhD in Environmental Chemistry and a MSc (Eng) in Environmental Civil Engineering from University of Otago, Dunedin, New Zealand and University of Liverpool, Liverpool, United Kingdom respectively. His current focus is on the development of FYP- internship with industrial research collaboration in the area of water technology and waste recycling technology. He also served as Scientific Committee member in Challenges in Environmental Science and Engineering, Australia since 2015, Member of International Water Association (IWA, UK) since 2010 and member of MOE Science Judge since 2017.

Soo-Ng Geok Ling passion for teaching and technology can be traced back to my early-professional days with her first job in supporting the transforming construction industry to use IT solutions in engineering projects. The reason? She likes getting people excited about how technology can help them to be efficient. She is now a senior lecturer in the School of Architecture and the Built Environment at the Singapore Polytechnic. She is committed to education through improving students' learning and mentor teaching staff through effective professional development. Also, check out her recent project in leading the School of ABE into a holistic integrated approach to foster self-directed learning in 6 diploma courses: https://rise.articulate.com/share/i-biu-PMFt1iwSHqCjJXIYvyMDvQBN7I.

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TOWARDS AN INTUITIVE AND OBJECTIVE ASSESSMENT FOR PROJECT-BASED MODULES

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ABSTRACT

Assessing student design-implement skills in project-based modules integrated with CDIO framework has always been a challenging task to teaching staff. Even equipped with written rubrics, staff still assess the students' performances based on their own understanding of observed students' achievements as well as staff's own interpretations of the given rubrics, which may vary from one teaching staff to another. This challenge is heightened for modules that have a large number of classes and involve more than 20 teaching staff, comprising both full-time and adjunct lecturers. The traditional rubrics often expect teaching staff to award marks ranging from 0 to 100 or from 0 to a preset maximum score. In reality, it is almost impossible to provide an equal number of different assessed works of students in different assessment fields to reflect that range of marks.

This paper thus examines how an intuitive and objective assessment for one such project-based module - Introduction to Engineering. By applying this model, the teaching members of IE can simply match all the possible observable project criteria from a dropdown list of descriptors such as “Optimal and neat layout”, “Good and neat layout” …etc. for learning outcomes relating to design-implement skills. There is no need to specifically ensure that each assessment field has the maximum score when assessing. For any possible ambiguous interpretations, photos of past students' work were captured and presented in another spreadsheet for reference. The work has also taken into account feedback and comments from 15 teaching staffs, collected via a questionnaire and another 4 via causal conservations. After evaluating the usefulness of the assessment, a few missing observable criteria have been suggested for inclusion in the improved version of the assessment. Teaching staff commented on the ease of use and intuitive aspects of the assessment provided. Through visual inspection of the submitted projects done by the students, teaching staff only need to select the matching appropriate descriptors from the dropdown list provided in an excel spreadsheet. Most importantly, the teaching staff can also now make use of the descriptors to provide quick and meaningful feedback to students to support their learning.

KEYWORDS

Learning assessment, project-based module, feedback, gradebook, design skills, implement skills, observable record, observable performance. CDIO Standards 11, 12

NOTE: Singapore Polytechnic uses the word "courses" to describe its education "programs". A "course" in the Diploma in Electrical and Electronic Engineering consists of many subjects that are termed "modules"; which in the universities contexts are often called “courses”.

BACKGROUND

Ever since the C-D-I-O approach has been adopted as the teaching methodology in Singapore Polytechnic, changes were made to the syllabi to incorporate the CDIO skills to develop the students' personal and professional skills and attributes; interpersonal skills of teamwork and communication; and system and product building skills. (Crawley et al. 2014; Pee S.H. & Leong H. 2005; Pee S.H. & Leong H. 2006, Leong H., Sale D. & Wee C.S.P. 2009)

In the School of Electrical and Electronic Engineering (SEEE), an Introduction to Engineering (IE) module was instituted in line with the CDIO model to introduce all the first year students (~800) to the field of engineering focusing on design-build experience. The module was designed with a strong focus on active experiential learning (Felder, 2009) which in turn aims to stimulate interest in and to strengthen motivation in students in the field of engineering through real world build-and-design activities. At the same time, students are given the opportunity to develop interpersonal skills of teamwork and communication while developing the basic skills of circuit board prototyping. It is expected that this learning method will improve students' learning outcomes and encourage students to develop cognitive and psychomotor skills.

The module runs for 4 hours a week for a total of 15 weeks in the laboratory environment every first semester of the year. The module comprises 40% summative assessment, 20% on assessing teamwork, communication and interpersonal skills with the remaining 40% on the design and build project work as shown in Figure 1.

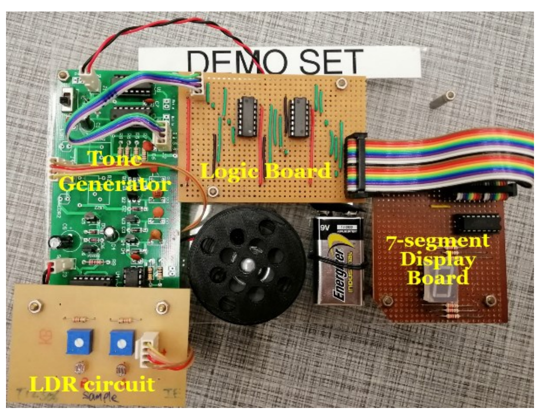

Figure 1. The complete project where students need to design, build, test and submit

Accordingly to Leong H., Sale D. & Wee C.S.P., (2009), the selected CDIO skill set has been implemented and has been sufficiently well received by both students and teaching staff. A number of assessment components were also developed to assess students' various skills to match the learning outcomes. Of all the assessment components, assessing student design-implement skills for the project work that weights 40% in total has always been an ongoing challenge to ensure reliability with the use of the given rubrics. To effectively illustrate how the design-implement skills were assessed in this module, let's look at a specific learning activity where a student is expected to learn the basic skills and techniques of circuit prototyping via their first circuit. For the sequent activities, the students were then expected to transfer what they have learnt to design and make their second board.

In this activity, students were told to build a simple 7-segment display board using a stripboard as shown in Figure 1 with the schematic diagram given in Figure 2.

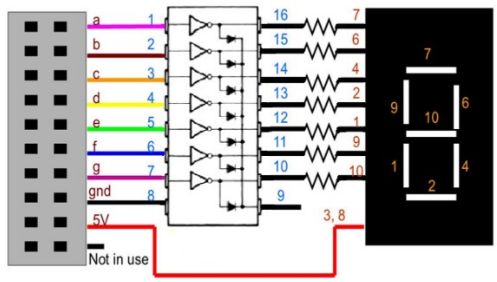

Figure 2. A simple 7- segment display schematic diagram.

As this is their first circuit board, the learning outcomes of this specific activity focus on the following:

- Understand the operation of the circuit diagram.
- Plan and assemble the components on a strip board to create a circuit.
- Able to apply the techniques of soldering and desoldering to an acceptable standard.
- Analyse the circuit and demonstrate the ability to trace the circuit board using the schematic diagram.
- Integrate and troubleshoot the project using appropriate instrument(s).

After the student has completed fabricating the board, he is then expected to test the board using a test board provided in the lab. The staff would then assess the student's performance with the given assessment rubrics as shown in Table 1.

Table 1. Scoring Rubrics for the 7-segment display board

Ability to construct the display board on stripboard and work independently (10 marks)	
0%-25%	Rarely.
25%-50%	Sometimes.
50%-75%	Often.
75%-100%	Very often.
Functionalities of the board (10 marks)	
0%-25%	Does not complete the task or task badly done.
25%-50%	Partially working circuit with much assistance.
50%-75%	Working circuit with some assistance.
75%-100%	Complete the task successfully and independently.
Overall workmanship of the completed project (ie good solder joints, components and cables are neatly laid out and connected) (5 marks)	
0%-25%	Does not complete the task or task badly done
25%-50%	Only partially met to an acceptable standard
50%-75%	Mainly met to an acceptable standard
75%-100%	Mainly met to a high standard

However, such generic descriptive scoring schemes often result in differences in marking for the same piece of work. The differences in mark can arise from a number of sources (José-Luis Menéndez-Varela & Eva Gregori-Giralt, 2018; S. Bloxham, 2009; J. Archer & B. McCarthy, (1988); B. McKinstry, H Cameron, R Elton & S Riley, 2004).

One common source is that individual lecturers will assess their students' performances based on their own understanding of students' observed achievements as well as staff's own interpretations of the given rubrics, which may vary from time to time and from one teaching staff to another. Two, as seen from the scoring rubrics, some of the assessment components (in this case, the workmanship was assessed at the end of the day) was assessed after the whole project which consisted of a few boards (see Figure 1), was completed. This makes it difficult even for one staff to maintain consistency as the students may have very different performance for different boards with varied levels of complexity. There are also teaching staff who tend to be more lenient in awarding marks than the presented work should deserve due to the time and effort the student had put in. All these become particularly evident whenever there is a group of staff coming together to assess the students' project work during an event or funded projects in our school. Staff have shown to present different views and differing levels of knowledge. This can thus result in varying expectations of students' level of understanding and emphasis may be on different aspects of the presented work. Another common source of error can arise from a lack of subject familiarity. All these challenges were heightened for this particular module as it involved about 40 classes each year with more than 20 teaching staff, comprising both full-time and adjunct lecturers.

Challenges

Establishing reliability is a prerequisite in accurate measurements of learning outcomes. When the results of an assessment are reliable, one can be confident to make generalised statements about a students' level of achievement, which is especially important when we are using the results of an assessment to make decisions about teaching and learning. However, there are few challenges which we should take note when redesigning the students' assessment. They are:

- Lecturers universally agreed that CDIO implementation has resulted in an increase in workload, resulting from the preparation and assessment involved, especially when cohort size is large and there are a number of assessment components (Felder, R., 2009). This means having multiple markers or double-blind marking as suggested by K. Willey & A. Gardner (2010) in an effort to achieve consistent grading is not realistic. Thus, if possible, scoring rubrics should be made simple and easy to follow without overwhelming the teaching members. This is particularly important in communicating to the students the rubrics as well as helping adjunct lecturers and new teaching members to cope with the workload.

- Improving the marking rubrics with more specific description is possible. However, the traditional rubrics often expect teaching staff to award marks ranging from 0 to 100 or from 0 to a preset maximum score. When there isn't sufficient different observable works of students to reflect the range of possible marks, this can produce a wider difference in the marks awarded.

DEVELOPING RELIABLE AND EASY-TO-USE ASSESSMENT

In order to redesign an assessment that is easy to follow and coherence to learning outcomes, we first break down the project into pieces of work as shown in Table 2 with reference to Figure 1. Based on the relative difficulty and importance of work, the individual boards were weighted accordingly as shown in Table 2.

Next, a self-learning guide with clear learning outcomes for the students was developed (see Appendix B). The learning guide serves dual purposees. Firstly, it providees opportunities for students to be more independent in their work and be able to self-assess their own hands-on work. This is especially useful during last semester (around March to June 2020) when Singapore entered into CircuitBreaker shutdown due to COVID-19. Secondly, it is easier for all the teaching staff to communicate to students their expectations and how their work is being assessed. As the self-learning guide is another piece of teaching and learning work, details on the effectiveness and how it was designed will not be discussed here.

Table 2. Boards that make up the final project and their weighted score.

Sequence	Breakdown of the boards to be submitted at the end of the day	Projected level	Weightings
1	The 7–segment display board	Easy	12%
2	Logic board	Intermediate	25%
3	LDR circuit & Tone generator	Easy	8%
		Total	40%

Using past experience, observations and collection of past students' work, all the possible observable project criteria was then listed. To illustrate, one can refer to Appendix A for the evaluation criteria for the 7-segment board. For any possible ambiguous interpretations, photos of past students' work were captured and presented in the same marking spreadsheet for reference. The marking scheme also provide some room for flexibility to the lecturers when assessing skills such as troubleshooting skills to ensure validity. This is because troubleshooting skills can be demonstrated at different level and depth. It also make the assessment more resilient when there is some allowance for changing conditions.

Once the evaluation criteria was established, Excel spreadsheet was then designed to capture all the evaluation criteria, weights and scores. To make the whole assessment process easy and intuitive, a drop down list with all the project criteria such as "Optimal and neat layout", "Good and neat layout" …etc. was listed. Figure 3. Show a screenshot on what a lecturer would see while using the spreadsheet for assessment.

7 -segment Board (Marking scheme)
Class : DCPE/FT/1A/01
***Instruction: Just select from dropdown list.**
Do not delete any columns or change the name of the sheet

S/N	Admin.No	Name	Planning and Components Layout	Overall workmanship of the completed project	Testing and troubleshooting	Total marks (15 marks)
1	1111111	Student 1	4- Good layout	3- Fair	3- Able to identify errors only	10
2	1111112	Student 2	5 -Optimal layout	3- Fair	4- Complete with some help	11
3	1111113	Student 3	4- Good layout 3- Optimal/Good layout with the need to redo 2- With 1-2 errors	4- Good	4- Complete with some help	11
4	1111114	Student 4	1- Many errors 0- Missing Work	4- Good	4- Complete with some help	12
5	1111115	Student 5	4- Good layout	4- Good	0- Missing work	8

Figure 3. Screenshot of the scoring rubrics for the 7-segment board in an Excel spreadsheet.

FEEDBACK FROM TEACHING STAFF

About two weeks after the end of the semester, an online survey were emailed to all the 24 teaching staff to gather feedback after using the new assessment spreadsheet. The questionnaire consists of a total of 6 items and the participants were asked to rank the first 4 items on a 5 point likert-type scale (1=strongly disagree to 5=strongly agree). The last 2 items are open ended questions. Staff were also given the option to call or arrange a meet up to discuss if they have any ideas for further improvement. The results for the first 4 items and the collected responses from the last 2 items are shown in Table 3 and Table 4 respectively.

Table 3. Teacher Staff Survey Results for item 1 to 4

No.	Question	Average Rating
1	The use of the "new" excel marksheet using the drop down list is easy and intuitive to use.	4.67
2	I find the new marksheet allows me to maintain better consistency in assessing student's performance as compared to the traditional marksheet.	4.53
3	The description of the different levels of competence seen from the drop down list is clear and well organized.	4.33
4	The description on the drop down list helps teaching staff to provide a useful and consistent feedback on student performance.	4.40

Table 4. Teacher Staff Survey Results for item 5 and 6

No.	Question	Responses
5	Do you think there is any competency level not captured in the marksheet? (You can email to me later if you need more time to think about it)	students who take shorter time to complete the project. " "For Logic bd design, assess if students can optimize the design (i.e. use min number of logic gates) " "nothing is perfect in this world, although it's already very well done, there is always room for further improvements. You already did a fantastic job"
6	Do you think there is a better way to improve the current assessment for project based modules? Do send us your ideas and suggestions. (e.g freeze panes to ease scrolling up and down or all the way to providing assessment that impacts learning.)	in competency level, to include if the board is completed and working, partially working? " "no need to picking bone from egg."

Though only 15 out of 24 teaching staff completed the survey, all but one gave the 5 or 4 as their responses to all the first 4 items. This clearly indicates that all find it easy to use, find the description clear and help them to provide consistent feedback on student performance.

The only item that received a low score of 2 was item 2. This means 1 out of 15 respondents did not agree that the new scoring rubrics help to maintain better consistency compared to the past rubrics. The comments were mostly valid as well, indicating improvement can be made by including the missed out criteria components. In addition to the 15 staff who did the survey, there were 4 staff who actually preferred to have a causal discussion with me on how the assessment can be further improved. These four staff members all commented that the assessment saved their time in the assessment and it was intuitive and easy to use. However, they found that a few observable criteria were missing and should have been included in the improved version of the assessment for the next run. The missing criteria mainly include the timely completion of the project, including more levels on the board completion and should reward students when they have shown to complete the project in the short time or uses very little resources to complete them. All these are valid and thus will be included in the improved version as shown in Appendix A for the 7-segment scoring rubrics.

CONCLUSIONS

The paper firstly discussed the challenges of ensuring reliable assessment with a large class size and having more than 20 teaching members. The use of an intuitive and objective assessment for the module – IE1 was then presented. Using the new assessment rubrics on Excel, teaching members only need to match students' submitted project/performance with all the possible observable project criteria from a drop down list of descriptors such as "Optimal and neat layout", "Good and neat layout" …etc. Such a carefully designed simple, task specific, scoring rubrics does not need to have the assessment field that share the same maximum score has the potential to produce increased reliable assessment. Majority of the teaching staff had also feedback that it is easy to use and require no pre-training. The dropdown list also helped teaching staffs to give very quick and consistent feedback. However, some criteria that was observed by teaching staffs were missing. Room for increased flexibility such as having different levels of board completed should be included as well to ensure validity of the assessment.

Though this approach not necessarily can overcome individual biases in the scoring (J. Archer & B. McCarthy,1988), the act of selecting the most matching appropriate descriptors from the drop down list provided in spreadsheet while inspecting a student's submitted work can help to average some of these effects. The author was also happy to find that teaching members do not find the use of the new assessment as an extra work. Quite a number even verbally told me it is time saving as there is less chances for them to remark to maintain consistency. Moving forward, the author will continue to improve the assessment by including the missing criteria making it more valid and reliable. This also include the possibility of gathering all the staff's grading spreadsheet to perform do a comparative analysis against some summative assessment the students are taking. We may also explore getting student to perform their own evaluation using the same rubrics. In this manner, we can then understand if the student understand the assessment criteria and the staff expectations of their work.

After all, more and more schools are using assessment data to help them make decisions. Thus, having easy to interpret, reliable and valid learning outcomes is always the first step.

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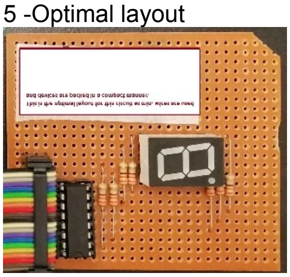
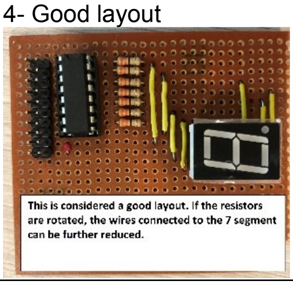
APPENDIX A

<table>
<tr><td colspan="3">7 – segment board scoring rubrics</td></tr>
<tr><td colspan="3">Layout plan</td></tr>
<tr><td>Evaluating Criteria</td><td>Marks</td><td>Improved Version</td></tr>
<tr><td>5 -Optimal layout

Using min. wires and design is compact.</td><td>5</td><td>-</td></tr>
<tr><td>4- Good layout

</td><td>4</td><td>-</td></tr>
<tr><td>3- Redo or Fair layout
i.e layout not as good as the first 2.</td><td>3</td><td>-</td></tr>
<tr><td>2- With 1-2 errors</td><td>2</td><td>2- With 1-2 errors/ Partial Complete</td></tr>
<tr><td>1- Many errors</td><td>1</td><td>1- Many errors/Partial Complete</td></tr>
<tr><td>0- Missing Work</td><td>0</td><td>-</td></tr>
<tr><td colspan="3">Overall workmanship</td></tr>
<tr><td>Criteria:</td><td>Marks</td><td>Improved Version</td></tr>
<tr><td>5- Excellent
Wiring is neat and at appropriate length, use the correct color code, solder joints look shiny,…etc</td><td>5</td><td>Not change.</td></tr>
<tr><td>4- Good</td><td>4</td><td></td></tr>
<tr><td>3- Fair</td><td>3</td><td></td></tr>
<tr><td>2- Poor/Partial complete</td><td>2</td><td></td></tr>
<tr><td>1- Partial complete</td><td>1</td><td></td></tr>
<tr><td>0- Missing work</td><td>0</td><td></td></tr>
<tr><td colspan="3">Testing and Troubleshooting</td></tr>
<tr><td>Criteria:</td><td>Marks</td><td>Improved Version</td></tr>
<tr><td>5- Complete with min. guidance</td><td>5</td><td rowspan="6">8- Complete on time without help.
7 - Complete on time + min. guidance
6- Complete on time + little help.
(e.g can identify errors but can’t solve)
5 - Complete on time + some help (e.g can’t identify all errors)
4- Partial Complete/not on time
3-Partial complete/not on time
2- Partial or Complete by getting others to troubleshoot for them frequently.
1-Get others to troubleshoot for them & not learning
0 -Missing work</td></tr>
<tr><td>4- Complete with some help</td><td>4</td></tr>
<tr><td>3- Able to identify errors only</td><td>3</td></tr>
<tr><td>2- Not trying enough/did not complete on time</td><td>2</td></tr>
<tr><td>1- Rely on others & not learning</td><td>1</td></tr>
<tr><td>0- Missing work</td><td>0</td></tr>
</table>

APPENDIX B

7 –Segment Board Self-Directed Learning Guide *To be successful in self-directed learning, one must be able to engage in self-reflection and self-evaluation of his/her learning goals and progress in a unit of study. To support your learning progress in IE1, we have created a list of learning milestones so that you are able to monitor and evaluate your own learning. If you can't achieve the learning milestones in your first attempt, don't get discouraged! List down the learning challenges in your BCA form! Discuss with your team member and lecturer and see what learning resources/strategies you need to overcome your learning challenges.*	
Name	
Admin No	
Learning goals: Learn the skills on how to make circuit on a stripboard Completion Date:	
While doing my layout planning, I am able to	
☐ plan the position of the components so that it uses the connections already on the stripboard as much as possible. (i.e. less connecting wires) ☐ label the numbering of the ICs, Vcc and Ground, …etc clearly on the planning sheet.	
For electrical safety & Housekeeping, I am able to	
☐ setup the soldering working area in a safe manner. ☐ ensure electrical safety practices and perform basic tool and equipment housekeeping (e.g. turn off the power when not using, wires do not fly all over while stripping) at all times.	
While fabricating the stripboard, I am able to	
☐ use RED wire for Vcc. ☐ use BLACK wire for Ground. ☐ use coloured wires to represent logic lines. ☐ use proper wire length and layout my wiring in a neat manner. ☐ apply solder such that the soldered joints looks smooth, shiny and cling to the metals for proper connections.	
Before I test the board,	
☐ I have visually inspected the board to check if there are any soldering problems. I am able to use the digital multimeter to carry out the test procedures to check if ☐ Vcc and Ground are not shorted. ☐ all the tracks between the pins of an IC are not shorted after breaking them. ☐ The logic inputs are not shorted (unless they are meant to) ☐ The ICs are properly wired to Vcc and Ground.	
While testing of the board, I am able to	
☐ test the board and show the working piece to my lecturer.	
While troubleshooting the board	
☐ I am able to explain how the circuit works (revisit the lecture slides on how the circuit works). ☐ I am able to identify the problem encountered. e.g. LED segment b is not working as intended. ☐ I am able to use the digital multimeter to identify and trace where the problem lies. ☐ I have done all the necessary checking and testing before I seek assistance from my lecturer.	

Lecturer in Charge: ____________________

Signature

BIOGRAPHICAL INFORMATION

Chia Chew Lin is the Academic Mentor of the School of Electrical and Electronic Engineering at Singapore Polytechnic. She loves to experiment with new teaching ideas to enhance students' intrinsic motivation in learning. Her current interests and focus is identifying the current learning problem or teaching ineffectiveness and work to improve on it.

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A REPORT OF CROSS-COURSE-TYPED PBL AND STUDENTS' SELF-ASSESSMENT

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ABSTRACT

National Institute of Technology, Sendai College, Hirose Campus has been conducting surveys on students' generic skills (GSs) through the standardized tests in Japan since 2014. The educational effect of our curriculum is confirmed by analyzing the survey results and by comparing our students' average scores with those of university students. From the results of this continuous survey, while it became clear that our campus curriculum was effective in helping students grow in both Literacy and Competency skills, it was also revealed that some Competency skills were not fully / could be further developed. Based on the survey results, we are trying to improve our curriculum and lessons focusing on students' skills that have not yet grown sufficiently. As an example of the improvements, we reorganized the classes of experimental practices and a cross-course-typed PBL was offered as an experimental subject for 4th-year students. By grouping students from different specialities and having them solve practical problems in groups, we tried to improve the students' skills of team activities, planning, and implementing. From social issues defined in the SDGs and issues related to COVID-19, various themes were selected, and the students seriously worked on them in PBL. In this paper, we will introduce practical attempts of the PBL to develop student's GSs.

KEYWORDS

Personal Skills, Interpersonal Skills, Project-Based-Learning, Evaluation of Generic Skills, Standards: 5, 7, 8, 11

BACKGROUND

In engineering education, it is important not only to help students acquire specialized knowledge and skills but also to cultivate their generic skills (GSs) to utilize the acquired knowledge and skills in the real world. CDIO Syllabus 2.0 also emphasizes the importance of GSs by defining "Personal and Professional Skills and Attributes" and "Interpersonal Skills: Teamwork and Communication." Hence, many educational institutions around the world are promoting students' GS development by introducing active learning (AL) and problem / problem-based learning (PBL).

National Institute of Technology, Sendai College (Sendai KOSEN) proposed an A^3 learning system to develop students' GSs in 2014 and carried out a large-scale reorganization of the curriculum into the one that incorporated many techniques of AL and PBL. While the curriculum was reorganized, the evaluation of students' GSs was conducted by an objective method, and the educational effect of the changes in educational methods has been continuously surveyed. In 2018, the survey from students' admission to graduation was completed, and the GS growth characteristics of our students were clarified. Kawasaki et al. reported at the 16th CDIO International Conference (CDIO 2020) that the GSs of Sendai KOSEN students grew steadily as their year progressed. On the other hand, a detailed analysis revealed that some skills did not improve, and Yajima et al. will report the results and propose some measures to improve those skills at IEEE global engineering education conference (EDUCON 2021).

We aimed to realize more effective GS development by improving the curriculum and educational contents based on the results of the continuous survey and started some attempts in 2019. As an example of improvement, in this paper, we will give a practical report on "cross-course-typed PBL (course-integrated PBL: CI-PBL)" to develop skills to be strengthened. This study is based on an annual GS continuation survey, but students have not taken the PROG test at the end of the PBL project. Therefore, in order to confirm the students' feelings of growth, self-evaluation of the students was conducted before and after the project. Although the student's self-assessment showed sufficient growth, we further plan to analyze the effect of the PBL by using the results of the PROG test in the future because the self-assessment is not considered to be absolutely reliable as the indicator of students' progress.

GENERIC SKILLS GROWTH CHARACTERISTICS OF STUDENTS AT SENDI KOSEN, HROSE CAMPUS

At our school, Progress Report on Generic Skills (PROG), which is a standardized test in Japan (Kawaijuku Group, 2020), has been used to evaluate students' GSs. The reason for adopting PROG is that it is an objective test and is widely used in higher education institutions in Japan. GSs are difficult to evaluate objectively and different evaluators can give different evaluations. By using PROG, we can avoid such subjective evaluations. Furthermore, there is a great advantage that we can compare our students' scores with the average scores of university students who took the same test. From the results of the continuous survey, it became clear that our students' GSs develop steadily as the year progresses. However, on the other hand, the comparison with the average value of university students revealed that some skills in the Competency part need to be further strengthened and developed.

Figure 1 shows the scores of 1st-year students (blue) and those of 5th-year students (red), who enrolled in 2014, in the main 3 categories and medium 9 contents in the Competency part. Here, the differences (red score minus blue score) is the growth score at our school. Also, as reference data, the average value of university students in 2018 is shown in black. As is clear from Figure 1, in the main categories, our students' "(3) Problem-solving skills" did not grow, and the score of the 5th-year students was lower than the average score of the university students. Also, although "(1) Teamwork skills" improved, the score of the 5th-year students was also slightly below the average of university students. Among the medium contents, "(3-2) Planning solutions" and "(3-3) Implementing solutions" were the skills that need to be strengthened in the future since no growth was seen or the growth was small and lower than the average value of university students. For "(1-1) Relating with others", "(1-2) Cooperating with others", "(1-3) Team management" and "(2-3) Behavior control", growth was observed. However, the scores were measured equal to or lower than the average value of university students. Therefore, we consider that these skills can be further improved. These results make it clear that our students' skills related to team activities, planning, and implementing must be strengthened.

REORGANIZATION OF EXPERIMENTAL PRACTICES

We are making many efforts such as lesson improvement to develop the skills related to team activities, planning, and implementing, our students' weaknesses revealed in the survey. As the biggest attempt, we have reorganized the contents of the experimental practices, and we will introduce the outline in this paper. The skills to be developed in the experimental practices before the improvement are shown as follows,

1st and 2nd years: acquisition of engineering literacy (how to write the reports and read the literature), elementary experimental techniques, presentation skills and elementary skills of collaboration.

3rd and 4th years: acquisition of advanced engineering literacy, and middle- and high-levelled experimental techniques, and skills of group activity.

5th year: comprehensive and practical problem-solving skills through graduation research (Project Based Learning).

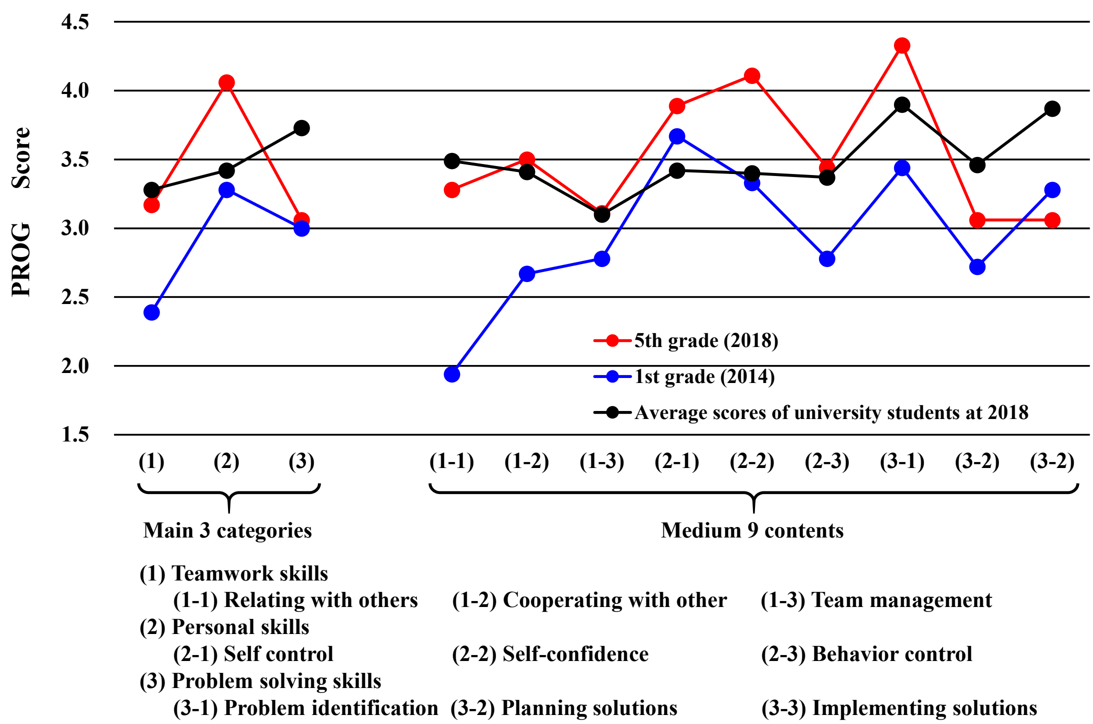


Figure 1. PROG scores of the detailed elements of Competency part.

Students were supposed to acquire the necessary skills gradually as the year progresses. The composition was strongly conscious of team activities, planning and implementing, however, it became clear from the continuous survey that these skills had to be further strengthened. Therefore, we reorganized the experimental subjects for the 3rd and 4th years. In the experiment of the 3rd-year students before the change, it was an "instruction type" in which the students conduct the experiment planned and scheduled by the teachers. This "instruction type" experiment was replaced by a "students' design and implementation type" in which the students themselves make an implementation plan with the group members and manage the schedule. By changing to the "students' design and implementation type", discussions, consultations and reflections within the group became active, and the students were able to be strongly aware of planning and progress management. In the self-assessment using the rubric of the 4-step evaluation before and after the experiment, almost all of the students felt that they were able to improve their skills such as independence, responsibility, teamwork, and self-management by one step or more. Yajima et al. plan to report specific improvement methods and evaluation results at EDUCON 2021 regarding the experimental improvement performed in the 3rd year.

Further development of the improvement of the 3rd-year experiment was carried out, and in 2020, a CI-PBL was offered in the 4th-year experiment. Students engage in more practical team activities by being grouped regardless of their course and conduct large-scale PBL for learning project management. In this paper, we report the implementation contents of CI-PBL and the results of self-evaluation of each skill of the students before and after PBL.

COURSE-INTEGRATED PBL

Sendai KOSEN is a five-year technical college where students aged from 16 to 20 study engineering. The Hirose Campus has three courses: Information Systems Course (Software), Information and Telecommunication Systems Course (Communication / Computer-Network), and Intelligent and Electronics Systems Course (Hardware / Electronic Devices). As one of the experimental subjects in the 4th year, CI-PBL was placed. CI-PLB is a compulsory subject and will be taken by all (about 120) students every year. Its format is 180 minutes (2 classes) per week for 15 weeks, and students get 2 credits. The students are divided into 24 groups regardless of their courses, and one support faculty member belongs to each group. This subject aims to improve selectively and efficiently the skills related to team activities, planning, and implementing by forming groups with students from different specialities and working on large-scale PBL. The theme of this year's PBL is "solving problems in the community and our school, or creating something useful and interesting". Furthermore, when setting tasks, conditions such as "making someone outside the group happy" and "making sure that some kind of challenges for the group is included" are imposed.

The schedule for CI-PBL is shown in Table 1. The first week is guidance (explanation of the purpose, goals to be achieved, evaluation method, schedule, and so on) and creating projects by individual students using the brainstorming method. A workshop on how to determine the theme of team activities (projects) by an expert is held in the second week. The third week is a workshop on project management and how to use a Work Breakdown Structure (WBS) and a Gantt chart. Every group prepares a WBS and Gantt chart in the 4th to 5th weeks, and a theme and project presentation by each group was held in the 6th week. In the 7th-11th weeks, they implemented their projects, and in the 12th week, a contest-styled outcome presentation was held. In the 13th to 14th weeks, they summarized and reviewed the entire project and made their final report. In the final week, all students will have a personal interview with the teachers.

At first, CI-PBL was planned to be conducted in a face-to-face class. However, due to the influence of the novel coronavirus (COVID-19) in 2020, implementation in a face-to-face should be avoided as much as possible. Fortunately, the National Institute of Technology, to which our school belongs, has a comprehensive license agreement with Microsoft, and every teacher and student has an MS365 account. Therefore, by utilizing Teams' online meeting function and team collaboration software "Miro", we managed to hold CI-PBL in online format up to the 6th week, which were a workshop, presentation and so on. The project was conducted face-to-face, while taking sufficient countermeasures against infectious diseases, such as putting as small a number of students in a classroom as possible. As a result, we were able to carry out the originally planned content on schedule without degrading the lesson quality.

Next, the themes of each groups' project are shown in Table 2. The themes ranged from projects dealing with social issues such as COVID-19, environmental issues, and drunk driving prevention to projects aiming to publicize our school or improving convenience. As an example of the project deliverables, the group 4's project "Development of a monitoring system for the congestion status of our school cafeteria", which won the award for excellence in the contest, is described.

Table 1. Schedule of Course-Integrated PBL

Week	Contents	Method, etc	Submissions
1	Guidance (explanation of the purpose, goals to be achieved, evaluation method, schedule, and so on) and creating projects by individual students using the brainstorming method	Online meeting, Individual work	
2	Workshop on how to determine the theme of team activities (projects) by experts	Online meeting	
3	Workshop on project management and how to use a Work Breakdown Structure (WBS) and a Gantt chart	Online meeting	
4	Decide the project theme and create WBS and Gantt chart	Online meeting, Team activities	Personal daily report, Team activity report, Self-assessment sheet
5	Create WBS and Gantt chart and prepare for the interim report meeting	Online meeting, Team activities	Personal daily report, Team activity report
6	Interim report meeting	Online meeting, Team activities	Personal daily report, Team activity report
7	Execution of the project	Face-to-face, team activities	Personal daily report, Team activity report
8			
9			
10			
11			
12	Achievements report meeting and Contest	Online, report video	Personal daily report, Team activity report, Voting card for a good project
13	Project summary and report preparation	Face-to-face, team activities	Personal daily report, Team activity report, Project report, Mutual-assessment sheet
14			

Table 2. List of themes of each group.

Group No.	Theme of PBL
1	Development of a time card using a QR code for attendance confirmation
2	Development of remote shooting system in refrigerator using Raspberry Pi
3	Development of a system that provides precautions when using an online system
4	Development of a monitoring system for the congestion status of our school cafeteria
5	Creating video content for our school PR
6	A project for ON / OFF automation of ceiling light
7	Development of Web application for tourists
8	A project to introduce our school through KARUTA
9	A project to make an easy-to-wash grater
10	Creation of our school introduction pamphlet
11	Project on improving the usage environment of personal computers
12	Creating an easy-to-understand school map
13	Development of smart disinfection system using human movement detection technology
14	School facility maintenance project that meets local demands and ecology
15	A project for visualization of classroom' environment
16	Manufacture of inexpensive and effective filters
17	Creating a school life guidebook for international students
18	Creating a pamphlet that conveys the attractions and dangers around our school and Ayashi Station
19	Creating a grasping system of submissions
20	A project for drunk driving prevention
21	Making tableware that is kind to the environment
22	Development of self-adjusting whip mixer
23	Creation of cards (KARUTA) with infectious disease countermeasures

To prevent COVID-19 infection, Group 4 developed a system that manages the number of people using the school cafeteria by posting the congestion status of the cafeteria on the website in advance. Figure 2 shows an overview of the created system. First, the inside of the cafeteria is photographed with a Web camera (a), and the number of users is counted using image processing technology (b). Next, the congestion status is calculated by dividing the counted number of users by the number of seats. By posting the calculated school cafeteria utilization rate on the website (c), anyone can know the congestion status of the cafeteria at any time. COVID-19 infections can be reduced by users in the school cafeteria checking congestion with this system and avoiding congestion. Next, Figure 3 and Figure 4 show the created WBS and Gantt charts for executing the project. Throughout the project, the students seemed to have acquired skills in team activities, planning, and implementing.

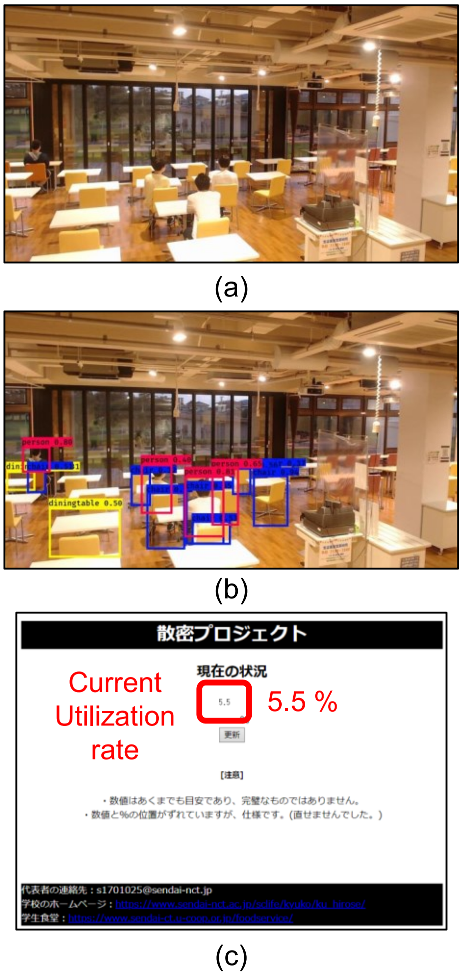


Figure 2. Overview of the created System of Group 4.

WBS : Work Breakdown Structure

content : Creating a Web system that shows the congestion status of the cafeteria

Achievement : Avoidance of congestion in the cafeteria

1.Preparation
- 1.1 Create a website
  - 1.1.1 Programing the contents of the site by html
  - 1.1.2 Specification of layout by css
  - 1.1.3 Addition action by Java script
- 1.2 Production
  - 1.2.1 Selection of equipment
  - 1.2.2 System design
  - 1.2.3 Design of fixing jig
  - 1.2.4 Debug
- 1.3 Negotiation
  - 1.3.1 Proposal to the clerk(cafeteria)
- 1.4 Announcement
  - 1.4.1 Creating a poster

2. Implementation
- 2.1 Installation of Web camera
- 2.2 Opening a Web site by XFREE
- 2.3 Notification of poster

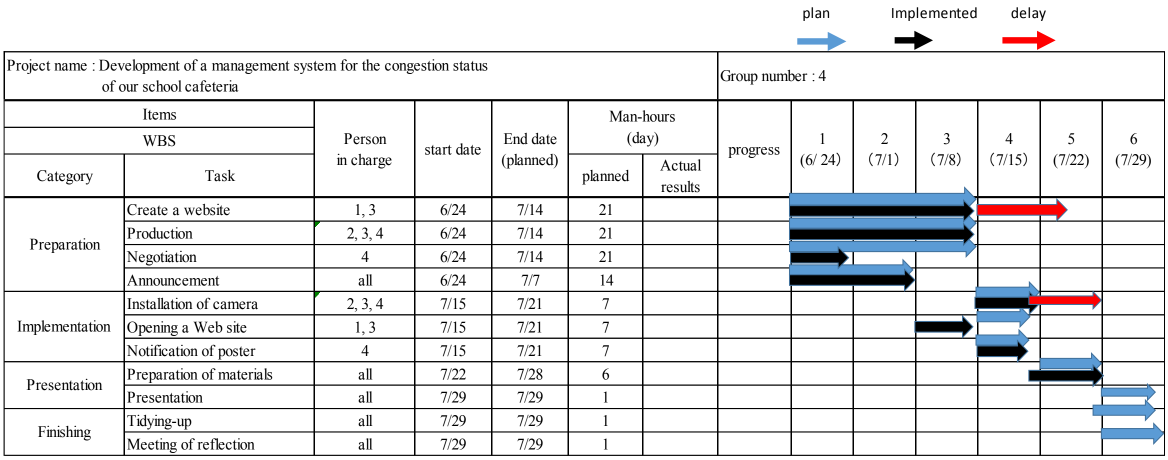
3. Presentation
- 3.1 Preparation of presentation materials
- 3.2 Presentation at the achievement briefing

4. Finishing
- 4.1 Tidying-up
- 4.2 Meeting of reflection

Figure 3. Work Breakdown Structure of Group 4.

SELF-ASSESSMENT OF GENERIC SKILLS BEFORE AND AFTER CI-PBL

The CI-PBL is a subject aimed at strengthening the skills in team activities, planning and implementing which our students need to develop. Since the GS survey using the PROG is an annual survey, it is not possible to measure immediately before or after this PBL. Therefore, as a skill for the success of the project as a team, we conducted self-evaluation of students before and after PBL on six elements related to independence and collaboration. The six elements of self-assessment are specifically "reflection on myself", "time management", "responsibility", "abilities to listen closely", "transmission power", and "skills of report, contact and consultation". Furthermore, after PBL, mutual assessments by the members in the same group and assessments by faculty members were also conducted, and these assessment results are described below.



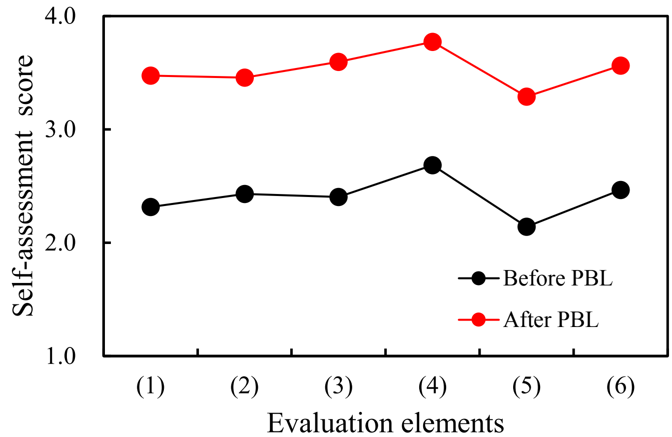
Project name : Development of a management system for the congestion status of our school cafeteria							Group number : 4						
Items / WBS		Person in charge	start date	End date (planned)	Man-hours (day)		progress	1 (6/ 24)	2 (7/1)	3 (7/8)	4 (7/15)	5 (7/22)	6 (7/29)
Category	Task				planned	Actual results							
Preparation	Create a website	1, 3	6/24	7/14	21								
	Production	2, 3, 4	6/24	7/14	21								
	Negotiation	4	6/24	7/14	21								
	Announcement	all	6/24	7/7	14								
Implementation	Installation of camera	2, 3, 4	7/15	7/21	7								
	Opening a Web site	1, 3	7/15	7/21	7								
	Notification of poster	4	7/15	7/21	7								
Presentation	Preparation of materials	all	7/22	7/28	6								
	Presentation	all	7/29	7/29	1								
Finishing	Tidying-up	all	7/29	7/29	1								
	Meeting of reflection	all	7/29	7/29	1								

Figure 4. Gantt chart of Group 4.

Table 3. Rubric for personal evaluation.

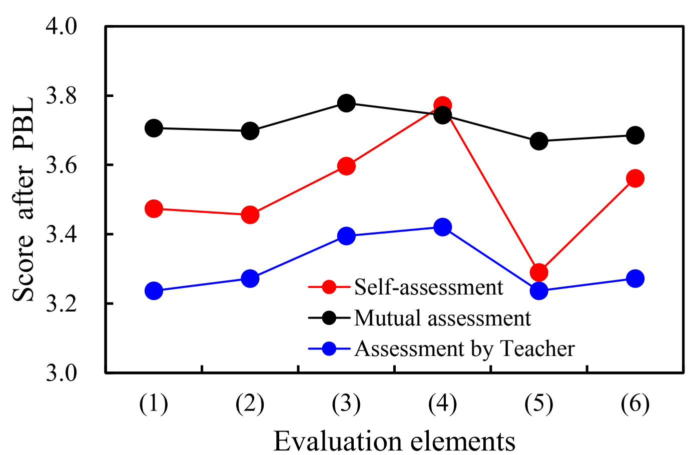
Levels	Skills to make a team project successful					
	Independence			Cooperativeness		
	(1) Reflection on myself	(2) Time management	(3) Responsibility	(4) Ability to Listen closely	(5) Transmission power	(6) Skills of Reporting, Communication and Consultation
4 (Exceeding Standard)	Student can make specific reflections on the personal goals they set each time.	Student can perform their tasks as planned or better.	Student can take positive action to play a role in a group.	In addition to Level 3, student can listen while confirming that they understand the content.	Student can devise ways to convey their opinions in an easy-to-understand manner, such as by drawing diagrams.	Student can report, communicate and consult in an appropriate manner.
3 (Proficient)	Student can set personal goals and reflect on them, but concrete reflections are sometimes inadequate.	Student are able to perform his/her tasks almost as planned, but sometimes he/she do it in a hurry just to meet the deadline.	Student can take actions to play a role in a group.	Student can listen to others while reacting to make it easier for the speaker to speak, such as "nodding."	Student can express their opinions, and most of what he/she say is correctly communicated to others.	Student can report, communicate and consult in an almost appropriate manner.
2 (Progressing)	Student can set personal goals, but they cannot look back enough.	Student can do his/her tasks, but sometimes is late for the deadline.	Student take actions to play a role in a group, but they are sometimes inadequate.	Student listen quietly to others, but often do not understand the content.	Student expresses their opinions, but often the content is not correctly communicated to others.	Student can report, communicate, and consult, but the content is often inadequate.
1 (Unsatisfactory)	Student cannot set personal goals or look back on his/her own.	Student misses the deadline for his/her tasks.	Students cannot take actions to play a role in a group.	Student is looking away, talking wastefully and doing irrelevant things when others are talking.	Student cannot express his/her opinions.	Student cannot report, communicate or consult.
Main evaluation sources	"Reflections on the goal" in personal daily reports, etc.	"Progress of implementation contents" of personal daily report, progress of Gantt chart, etc.	Project initiatives, meeting behavior, etc.	Attitudes when others are speaking at the meeting, etc.	Remarks at meetings and team activities, etc.	Reporting, Communication and Consultation at meetings and team activities, etc.

Table 3 shows the rubrics used for the assessments. The six skills of independence and collaboration were assessed by defining 1 to 4 criteria in the rubric. Figure 5 shows the self-assessment results before and after the PBL. The results are expressed by using the average score of all students. It is apparent from Figure 5 that the self-assessment scores after PBL is 1.0 point or higher than those before PBL in all elements. It can be seen that students felt a big growth subjectively through the CI-PBL. Next, Figure 6 shows the results of the assessment of themselves, mutual assessment by group members and assessment by teachers after PBL.



(1) Reflection on myself **(2) Time management**
(3) Responsibility **(4) Ability to Listen closely**
(5) Transmission power **(6) Skills of Reporting, Communication and Consultation**

Figure 5. Self-assessment results before and after PBL.



(1) Reflection on myself **(2) Time management**
(3) Responsibility **(4) Ability to Listen closely**
(5) Transmission power **(6) Skills of Reporting, Communication and Consultation**

Figure 6. Self and Mutual assessmentand assessment by teacher after PBL.

From Figure 6, it is measured that the score of mutual assessment is the highest, followed by the self-assessment, and the teacher's assessment is the lowest. It is considered that the Japanese temperament, which is considerate towards each other, is observed in the result that the mutual evaluation among students is the highest. As for the result that student self-assessment was observed higher than that of teachers, similar results have been observed in another survey. Another survey of our students' GSs, reported by Wako et al., found that the scores tended to increase in the order of "direct evaluation by teachers", "objective evaluation by standardized test (PROG)", and "subjective evaluation by students themselves". In the case of this survey as well, therefore, a true score may be between the student's self-assessment and the teachers' assessment. Hence, in the 6 evaluation items, the scores were located between 3.2 and 3.8 on a 4-point scale, and it is considered that the CI-PBL was able to sufficiently promote the growth of the targeted skills. These results on independence and cooperation are planned to be analyzed for the correlation of the results of the upcoming PROG test this year. Furthermore, the skills related to implementing, which have not been evaluated in this study will be planned to be evaluated using PROG results in the same way. The results of detailed analysis using the PROG survey will be reported in the near future, including the correlation with student self-assessment.

CONCLUSION

Since 2014, Sendai KOSEN, Hirose Campus has been conducting surveys on students' GSs through standardised tests in Japan. The educational effect of our campus is measured by analyzing the survey results and comparing them with the average scores of university students. While through the campus curriculum the students grew in both Literacy and Competency overall, they failed to develop in some elements of Competency sufficiently.
Curriculum and lesson improvements are being made to improve students' skills in our campus. As an example of the improvements, we reorganized the subjects of experimental practices and a cross-course-typed PBL was offered as an experimental subject for 4th-year students. By grouping students from different specialities and having them work on practical problems, we tried to improve the students' skills of team activities, planning, and implementing. From social issues defined in the SDGs and issues related to COVID-19, various themes were selected, and the students seriously and happily worked on them in the PBL class. It became clear from the results of self-assessment that the students felt their growth through the experience.

There were variations in the degree of support and facilitation of the teachers in charge of each group, and there were also large variations in the evaluation by the teachers, so in the future we intend to share the degree of support and evaluation criteria thoroughly. Also, we plan to analyze the correlation with the results of the standardized test, which is planned in the near future, and to utilize it for improving the CI-PBL.

ACKNOWLEDGMENT

In the CI-PBL, one faculty member is assigned to each group, so 24 faculty members cooperated in implementing PBL. We would like to express our heartfelt gratitude not only for the class hours but also for the many efforts they have made, such as attending the project management workshop in advance and providing overtime lectures. Furthermore, the continuous survey is supported by Japan's Ministry of Education, Culture, Sports, Science and Technology's program for accelerating university education. We thank all the faculty members, including the President of the National Institute of Technology, Sendai College for contributing to the improvement of education.

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DESIGNING BLENDED-TYPE INTEGRATED LEARNING EXPERIENCE USING CORE PRINCIPLES OF LEARNING

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ABSTRACT

This paper shares the experience in designing a blended learning to provide an integrated learning experience (CDIO Standard 7) for students to develop a core competency required in the workplace. The integrated learning experience is designed using a set of core principles of learning. Specifically, the integrated learning experience is contextualized to develop the required skills and desired attitude in carrying out line-tracing in the chemical process industries. The students are from the Diploma in Chemical Engineering, who spent about 4 hours per week on the learning tasks, for a total of 3 weeks. In blended learning approach, students first learn how to read an engineering drawing known as the piping and instrumentation diagram (P&ID), a blueprint for a chemical plant. This is achieved through an e-learning package developed by the author. Students then learn about skills in conducting line-tracing, based on a pilot plant in the workshop. They are then given the opportunity to practice line-tracing using the same pilot plant. Lastly, they are required to sketch their own P&ID for other pilot plants that they will later use in subsequent activities. The paper first provides a brief background of line-tracing and P&ID, to set the context (CDIO Standard 1) for designing the integrated learning experience, and the key desired learning outcomes (CDIO Standard 2) are explained. The paper then gives a quick overview of core principles of learning and proceeds to provide detailed explanation of how the integrated learning task is designed. The paper then elaborates on the choice of collaborative learning as key pedagogy, and the design leveraged on students' prior learning in chemical plant operation, teamworking and self-directed learning (CDIO Standard 3). The paper also addresses the assessment of student learning (CDIO Standard 11). High effect size strategies to scaffold student learning (such as workbook, feedback and reflective practice) and promote collaboration, as well as measures to evaluate effectiveness of teamworking are also shared. The latter requires students to carry out self and peer assessment using an online platform, which automatically calculates the Self and Peer Assessment (SPA) factor and the Self-Assessment to Peer Assessment (SAPA) factor. Lastly, as part of continual improvement (CDIO Standard 12), the paper concludes with findings of student learning experience via a survey, the author's own reflection and suggestions to further enhanced the learning from such an endeavour.

KEYWORDS

Core Principles of Learning, Blended Learning, Standards: 1, 2, 3, 7, 11, 12

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

INTRODUCTION

A key area of employment for student graduating from the Diploma in Chemical Engineering (DCHE), Singapore Polytechnic is in the chemical processing industries, taking on positions as process technicians or engineering executives. One key competency in this job role is the ability of reading a blueprint of the chemical plant known as the piping and instrumentation diagram or P&ID in short. The importance of the P&ID cannot be understated: it provides key information about the plant including all equipment, instruments, valves, pipes and piping components, as well as key process parameters (temperature, pressure, flow rate, etc) and material (feed, intermediate, product, by-product, utilities, waste, etc) and energy flows in the plant. There are represented by symbols with suitable abbreviations and nomenclature. The process technician familiarise himself or herself by walking with the chemical plant using the P&IDs. The P&IDs are also referenced every time any modification is to be made to the plant; and updated after the modifications were made. One main challenge is that, despite the availability of international standards, the use of different symbols, abbreviations and nomenclature are prevalent among chemical companies' own in-house system, plant design contractors and plant design software vendors. A chemical company can easily end up with different P&ID systems, much to the frustration of its engineers and process technicians.

P&ID reading and line-tracing are taught to DCHE students in Year 1, Semester 2, in a module entitled *Laboratory & Process Skills 2*. This module aims to impart in students various laboratory skills and process skills, chief among the latter are the P&ID reading and line tracing. The module is non-examinable, and assessment is based fully on report submissions; whereby students need to complete 10 learning tasks and an assignment over a 15-week period (Table 1). The first 3 learning tasks (P01 to P03) are continuation of laboratory skills that was started in another module, *Laboratory & Process Skills 1* taught in Year 1, Semester 1. The integrated learning experiences on P&ID reading and line tracing (P04, P05 and P06) are covered in 3 Parts in the following 3 weeks. These tasks are meant to prepare students for 4 subsequent activities in plant operations (P07 to P10).

Table 1. Schedule of Activities for *Laboratory & Process Skills 2*

Week	Activity Number and Name / Description		Comments
1	P00	Safety Briefing, Teamwork Exercise, Mini-Workshops on Thinking & Self-Directed Learning (SDL)	Student complete teamworking sheet (same as Semester 1), self-assessment of SDL skills
2	P01	Investigation on Parameters that affect Leaching	Lab skills on Design of Experiments
3	P02	Study on Sensible and Latent Heats – Part 1	Lab skills in planning experiments using SDL + Survey 1 after P03
4	P03	Study on Sensible and Latent Heats – Part 2	
5	P05	P&ID Reading and Line-Tracing Part 1 (e-Learning)	Feedback on Reports for P01-P03 (during P04) Process skills + SDL in chemical plant operation, and chemical process safety Debrief P05 (during P06) Teamwork Measurement 1
6	P04	P&ID Reading and Line-Tracing Part 2, including Process Hazards Analysis	
7	P06	P&ID Reading and Line-tracing Part 3, sketching of P07-P10 P&IDs	
8	-	Mid-Semester Test (Not applicable for this module)	Survey 2
9-11	-	Semester Break	Assignment on P&ID Reading
12	P07	Fluid Flow Pilot Plant & Utility Systems	Weeks 12-15: Process skills in plant operation (Rotation, 1 pilot plant per group per week) Week 16: Survey 3 + Teamwork Measurement 2, Briefing on preparing for next stage (Sem 1 Year 2)
13	P08	Shell-and-Tube Heat Exchanger Operation	
14	P09	Multiple Pump Test Rig	
15	P10	Double-Pipe Heat Exchanger Operation	
16	-	Debrief & Wrap-Up	
17	-	Spare week for any make-up class	NIL

BLENDED LEARNING APPROACH TO INTEGRATED LEARNING EXPERIENCES

There are various definitions of blended learning, and the purpose of this paper, it is suffice to use one offered in the Oxford Dictionary: a style of education in which students learn via electronic and online media as well as traditional face-to-face teaching.

As can be seen in Table 1, the integrated learning experiences of interest in this paper is the one on P&ID reading and line tracing, imparted to students over a 3-week period. It starts with Part 1 (in P05) which is delivered fully online in an asynchronous manner, as part of e-learning. A series of 11 short videos were created using PowerPoint with narratives and posted to YouTubes for students to access and watch on their own time. Parts 2 and 3 are carried out face-to-face in the laboratory, where Part 2 (in P04) continues to build on P&ID reading skills developed in Part 1 to developed line-tracing skills; and lastly Part 3 (in P06) requires students to apply the skills to trace the lines and sketch P&IDs for various pilot plants.

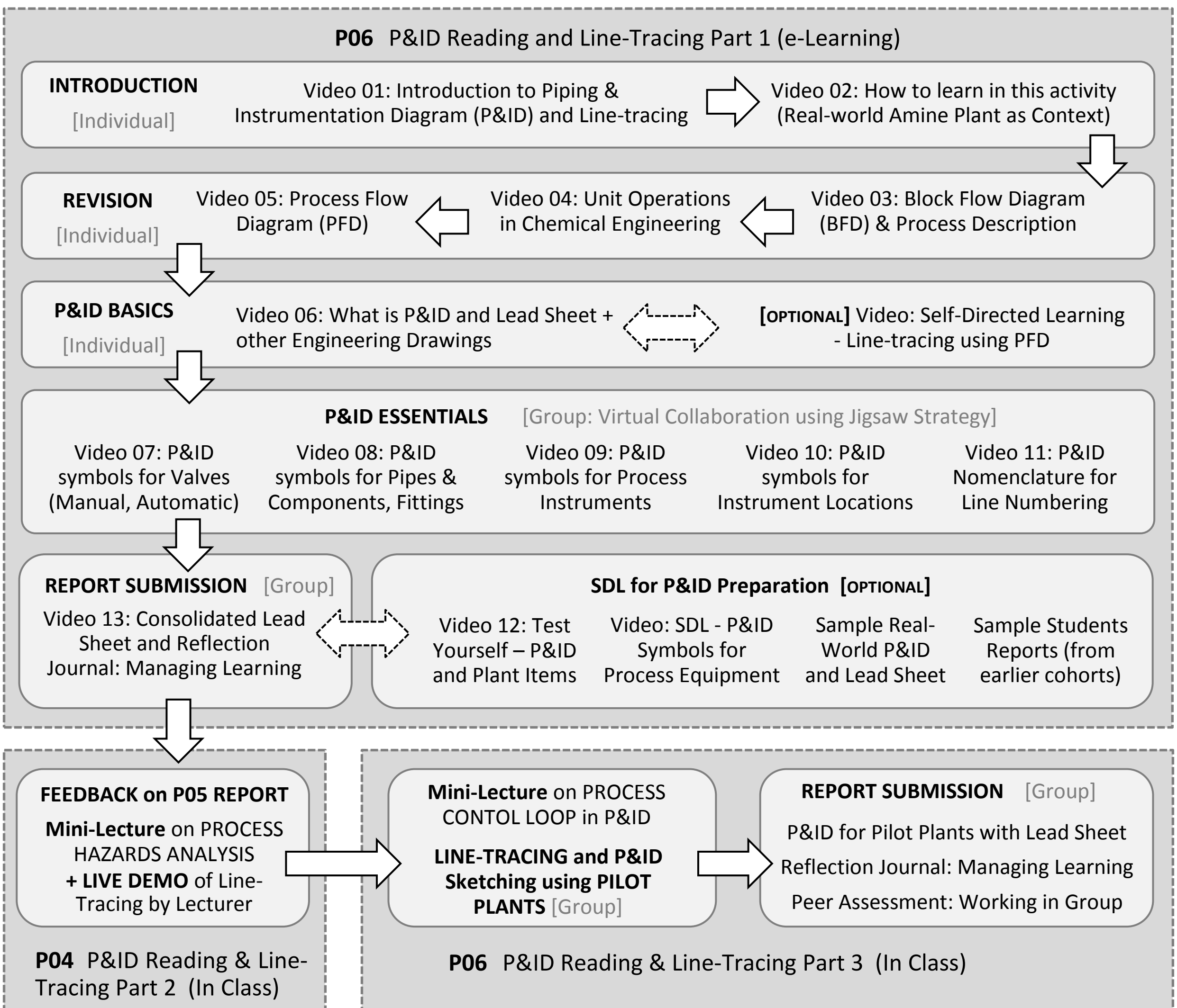

Figure 1. Blended Learning for P&ID Reading and Line-Tracing

The blended learning aims to simultaneously develop the technical knowledge in P&ID reading and line-tracing, as well as skills and attitudes in preparing a P&ID (which is a form of graphical

communication for chemical engineers), self-directed learning skills in learning about P&ID symbols, and teamwork in completing the various assignments, which was deliberately designed to the very challenging for any one student to complete on his/her own.
The context for learning (CDIO Standard 1) is clearly explained to students, which is based on the job role for process technician as spelt out in the Energy and Chemicals Skills Framework (Cheah et al, 2019). The technical aspects of the learning outcomes (CDIO Standard 2) are:

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

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

In addition, students are informed that there will be 2 touchpoints where teamwork measurement exercise will be carried out (Table 1) where they are required to do self- and peer evaluation based on them working together in teams.

DESIGNING INTEGRATED LEARNING EXPERIENCES USING CORE PRINCIPLES OF LEARNING

Sale's 10 Core Principles of Learning (Sale, 2015), as shown below, are used to guide the design of integrated learning experiences which is then delivered using the blended learning approach:

CP01 Learning goals, objectives and proficiency expectations are clearly visible to learners
CP02 Learners prior knowledge is activated and connected to new learning
CP03 Content is organized around key concepts and principles that are fundamental to understanding the structure of a subject
CP04 Good thinking promotes the building of understanding
CP05 Instructional methods and presentation mediums engage the range of human of senses
CP06 Motivational strategies are incorporated into the design of learning experiences
CP07 Learning design takes into account the working of memory systems
CP08 The development of expertise requires deliberate practice
CP09 A psychological climate is created which is both success-orientated and fun
CP10 Assessment practices are integrated into the learning design to promote desired learning outcomes and provide quality feedback

These principles are based on his extensive review of the literature on human learning and studies on effective teaching professionals in a range of educational contexts. They are not exhaustive or summative as new knowledge and insights will continually enhance our understanding of human learning and the implications for how we teach. Furthermore, just as combining high effect methods can have a powerful overall impact on learner attainment, as captured in Hattie's (2009) analogy of 'Russian Dolls', the same applies to the thoughtful and creative application of core principles of learning.

The use of these Core Principles of Learning in the design of integrated learning experiences (CDIO Standard 7) is further illustrated below, using the design of Integrated Learning Experiences for activities in P05, which as noted earlier is delivered via e-learning, as shown in Figure 1 earlier. In the sections that follow, other relevant CDIO Standards impacted are also highlighted, to illustrate the inter-dependence of these standards.

CP01: Learning goals, objectives and proficiency expectations are clearly visible to learners

The learning context and learning outcomes were spelt out at the beginning, and repeated at suitable intervals, and emphasized again in Report Submission section. Explicitly taught on Week 1 (Table 1) are Sale's Model of Thinking (Sale, 2015) and SP's Model of Self-Directed Learning (SDL) (Cheah et al., 2019). These are repeated multiple times in various e-learning narratives and in-class PowerPoint slides.

CP02: Learners prior knowledge is activated and connected to new learning

As shown in Table 1 and Figure 1, the learning tasks are sequenced to take place over a 3-week period to allow sufficient time for students to grasp the contents and make meaningful connections in the learning. The activity starts with Part 1 (P05) that introduces students to P&ID reading, by building on their earlier knowledge of other engineering diagrams, namely the BFD and PFD; and fundamental knowledge of typical equipment and processes in a chemical plant, as well as the importance of various process variables such as temperature, flow rate, composition, level and pressure (Figure 1: Videos 01, 03, 04 and 05). Students learnt these topics in the module *Introduction to Chemical Engineering* in previous semester. Students are then introduced to P&ID in Video 06.

The above also serves to illustrate how curriculum integration of technical content is being carried out in DCHE (CDIO Standard 3). In CDIO, curriculum integration emphasizes the infusion of skills and attitudes alongside the technical content. Students are reminded to maintain a growth mindset and to use the teamworking skills they learnt in another module *Laboratory & Process Skills 1* in the previous semester (Week 1, in Table 1). In addition, students are required to exercise SDL skills imparted in earlier activities (covered in P02 and P03 in Weeks 2 and 3, Table 1, for laboratory skills) in the context of P&ID Reading (Cheah, 2020). To give them an idea of what the line tracing process entails and how SDL can be used, an optional video demonstrating how a simplified process can be done using the PFD, a document that they are already familiar with.

CP03: Content is organized around key concepts and principles that are fundamental to understanding the structure of a subject

Content is organized around understanding the P&ID of an amine processing plant, commonly found in the chemical processing industries. The P&IDs of the plant is derived from a real-work operating unit that the author worked on, in his previous place of employment prior to joining the academia. Students are therefore exposed to the actual complexity of a chemical plant. In Part 1 (P05), students are taken through the structure of a plant P&ID, emphasizing a master reference section known as the Lead Sheets, which is like a pictorial dictionary comprising all the symbols, abbreviations and nomenclature for various plant items organized into different categories of equipment, valves, instruments, pipes and piping component, etc. These are offered as “P&ID essentials” in the form of Videos 07 to 11 (Figure 1). The technical outcome of P05 is to prepare a Lead Sheet comprising all the P&ID symbols for the different categories of plant items. One of the key requirements from students is to reconcile the differences, and at times conflicting, symbols used by different parties; for example, a plant item with 2 or more different symbols from different vendors or contractors, or the same symbol used by 2 different vendors and assigned to 2 different plant items. This requirement adds realism to the learning experience, as this is indeed how the real world is liked.

Part 2 (P04) then built of the learning from Part 1 (P05), where students are now introduced to techniques of line-tracing and identifying process hazards. Then Part 3 (P06) built on the learning from Part 1 (P05) and Part 2 (P04) whereby students sketch their own P&IDs for assigned pilot plants based on the line-tracing that they conducted.

<u>CP04: Good thinking promotes the building of understanding</u>

and featured regularly in various topics covered, as illustration on how to use it, as well as reminder for students to use it. Cutaway views of plant items in particular various types of valves, or piping components. In the video for line-tracing using PFD, guiding questions or prompts are used to guide students in the thinking process. Techniques of breaking down a seemingly complex problem into its constituent parts – itself an application of good thinking – are taught to students, for example to start with the familiar, look for similarities or repeat occurrence of same symbols, logical deduction, are covered.

<u>CP05: Instructional methods and presentation mediums engage the range of human of senses</u>

In the blended learning used in P05, real world pictures of plant items are used, alongside with vendor drawings, YouTube videos, animations curated from vendors, etc are used. 2 set of learning documents – one Instruction Manual, and one Workbook – are made available to students. In the face-to-face sessions for P04 and P06, students get to touch and feel actual cutaway models of various types of valves when they are working in the laboratory; and in P06 they get to walk around various pilot plants to complete the line-tracing process and carry out process hazards analysis with real plant items, albeit on pilot plant scale.

<u>CP06: Motivational strategies are incorporated into the design of learning experiences</u>

Various scaffolds and supports are made available. One main item is the use of Workbook to help student keep track of their progress during the e-learning of P05. This approach has been shown to be effective in engaging students in their learning (Nathan, 2010). There are also short, self-test learning tasks embedded in each video to help students assess their own learning. Hints are given as appropriate. Also made available (see Figure 1) are: (1) rubrics for preparing Lead Sheets, customized to preparing lead sheet and line tracing, so that students are aware of the expected performance standard; (2) samples of not-so-good reports from earlier cohorts that did not meet desired expectations; (3) interactive web-based SDL for line-tracing, with guidance questions for each step of the process; and (4) a comprehensive 40-question self-evaluation that can be taken at the end of the e-learning process (Video 12 in Figure 1).

CP07: Learning design takes into account the working of memory systems

The entire learning journey is split into 3 sessions, with P05 being conducted via e-learning whereas P04 and P06 are face-to-face, where each session lasts 4 hours. The learning progression in P05 is structured to engage students in understanding P&ID symbols in bite sizes. Each major topic is segmented into short sections, punctuated with small activities to reinforce the content covered and group exercises before moving on to the next topic. Summary of tasks covered are included just before instructions for report writing, to remind students of the topics learnt and follow-up needed in report submission. Students were also briefed on how they should approach the learning task in P05 (Video 02).

CP08: The development of expertise requires deliberate practice

Besides the self-test learning tasks embedded in each video in P05, there is also a separate. non-assessed set of 42 questions (Video 12) at the end of P05 for students to test their understanding. These questions cover the full range of topics in P05 covered earlier. Many of these questions require students to use knowledge from different topics, thereby creating an awareness among students on how they should integrate their learning from the various topics covered. In P04, students carried out line-tracing on their own after watching the lecturer demonstrated the process. In P06, they carried out more line tracing and P&ID sketching on their own.

CP09: A psychological climate is created which is both success-orientated and fun

The questions posed at the end of each topic are relatively easy, and presence of Model of Thinking prompts students to use certain thinking heuristics make the task achievable. Lecturer serving as facilitator also model the desired behaviour. Sharing of personal experience and near-miss stories also helped. Many of the learning tasks are made bite-size by having each team member being responsible for one section of the task; whereby they then collectively piece together all members' answers to address the question raised. To this end, students were taught how to use the jigsaw approach in collaborative learning.

CP10: Assessment practices are integrated into the learning design to promote desired learning outcomes and provide quality feedback

Most assessments are formative in nature, introduced at the end of each short topics in the case of P05, which is conducted via e-learning format. For P04, interactive question and answer format (active learning) is used in class as the lecturer take the class through the step-by-step line tracing and thinking process, based on a selected section of a plant's operating manual. Emphasis is made on understanding the rationale for carrying out a prescribed step and potential consequence of failure to adhere to the procedures; instead of merely following what is prescribed in the manual. For P06, students are given time in class to work on more activities, again using collaborative learning. Feedback is largely given in real-time based on work done by students. Reports (summative assessment) are marked and promptly returned to students within a week, with detailed comments, and they are given the opportunity to improve their P&ID lead sheet.

EVALUATION OF STUDENT LEARNING AND TEAMWORKING EXPERIENCES

Two instruments were used: one was a survey questionnaire for the blended learning approach for learning P&ID; and another was an online tool for teamwork measurement. For the survey questionnaire, details are not included in this paper due to constraint in the number of pages. Suffice to note that the survey is rather exhaustive and we had the liberty to craft probing questions to elicit responses specific to the learning tasks in P04, P05 and P06.

For measuring teamwork, we used the online assessment tool that computed two factors namely SPA (Self and Peer Assessment) and SAPA (Self-Assessment to Peer Assessment) based on student responses to a feedback form (Willey & Gardner, 2007; Freeman & Willey, 2006). In our adaption of the method, each student is required to complete the feedback based on 7 questions. The first 5 questions require each student to rate himself/herself and his/her team members on 5 dimensions – Competency, Team Contribution, Interaction with Team Members, Keeping Team On-Track, and Quality Work – using the Likert 5-point scale (“1 – Never”, “2 – Rarely”, “3 – Occasionally”, “4 – Usually” and ‘5 – Always”). The other 2 questions are open-ended: and each student is to provide input on what one appreciates about one’s team member, and a request from one’s team member.

The first factor calculated, SPA, provides feedback about a student’s performance compared to the average performance of all members in the team. It can be used as a weighting factor to change a team mark for a project (stage) into an individual mark. For example, if a team’s project mark was 80 out of 100 and a team member receives a SPA factor of 0.9, he/she would receive an individual mark of 72 to reflect a lower-than-average team contribution as perceived by a combination of the team member and his/her peers. Alternatively, if not used to moderate summative assessment the SPA factor can be used formatively to assist in student development (CDIO Standard 11).

The second factor calculated, SAPA, is the ratio of a student’s own rating of himself/herself as compared to the average rating of contribution by his/her peers. This has strong feedback value for future development e.g. using self-critical reflection. It provides students with feedback how the student perceives his/her own contribution relative to how his/her team perceive his/her contribution. For example, a SAPA factor greater than 1 means that a student has rated their own team performance higher than they were rated by their team peers. Conversely, a SAPA factor less than 1 means that a student has rated their own performance lower than they were rated by their peers. The possible combinations are shown in Table 2.

Table 2. Teamwork Measurement: SPA and SAPA Factors

	SPA < 1.0	**SPA = 1.0**	**SPA > 1.0**
SAPA < 1.0	1. Your performance is below expectation and your self-assessment is too low.	2. Your performance met expectation, but your self-assessment is too low.	3. Your performance exceeds expectation, but your self-assessment is too low.
SAPA = 1.0	4. Your performance is below expectation and your self-assessment is about right.	5. Your performance met expectation and your self-assessment is about right.	6. Your performance exceeds expectation, and your self-assessment is about right.
SAPA > 1.0	7. Your performance is below expectation and your self-assessment is too high.	8. Your performance met expectation, but your self-assessment is too high.	9. Your performance exceeds expectation, but your self-assessment is too high.

Results for both SPA and SAPA in the range of 0.95 to1.00 is considered Acceptable Teamwork, and in the range of 1.00 to 1.05 as Good Teamwork.

DISCUSSIONS ON FINDINGS

For the survey questionnaire, a total of 87 students participated, out of 7 classes totalling about 140 students, i.e. a response rate of about 62%. The key findings are shown in Table 3. Overall, majority of students find the blended learning approach either useful or very useful in helping them learn about P&ID reading and line tracing. However, comparing P05 (Statement 1) which is e-learning, with P04 (Statement 2) and P06 (Statement 3) which is face-to-face, it can be seen that students tend to value more face-to-face interactions. This may be due to the lack of interactions between students and facilitator for P05, as not all avail themselves to students during e-learning. And perhaps not too surprising, majority of students (Statement 4) are still not so sure of their ability to handle similar tasks for more complex plants in the real world. We see this as positive sign that most of them possess the growth mindset that was instilled in them since Semester 1 of Year 1. Other findings include the usefulness of instruction manual and workbook used to guide the learning process (69.0% Strongly Agree or Agree; 27.6% Somewhat Neutral), and the somewhat lukewarm on the use of Reflective Journal (49.4% Strongly Agree or Agree; 32.2% Somewhat Neutral). The rest of the findings identified various areas that proved challenging to students in reading or using P&ID, and 5 students (or 2.3% of respondents) who claimed that they still do not know how to conduct a line tracing.

On the other hand, for SPA/SAPA teamwork measurement, due to this being the pilot year the initiative is introduced, we have very limited data to work on. For DCHE, the Course Management Team decided to pilot this with one module per semester, starting with Semester 1 of Year 1, with 2 selected classes only. In fact, it was the author's initiative to carry out the teamwork measurement for this blended learning activity, i.e. not part of the DCHE pilot run. He tested this with the one class (in Semester 2 or Year 1) where he served as the facilitator. Although ALL students in this class completed the SPA/SAPA assessment, only 11 of them completed the survey questionnaire. The findings are shown in Table 4.

Despite the small sample size, we are able to make some inferences on the findings. Comparing the figures in Table 4 with that in Table 2, it would appear that with the exception of several outliers, most students in the class are quite 'on target' in terms of how they evaluate themselves and their team members. This can be compared with the findings from the survey questionnaire, namely student responses to Statements 5 and 6 (Table 3). Students generally reported good or very good teamworking in both activities that require then to work effectively in teams (P05: learning P&ID symbols and preparing lead sheets), and P06 (line tracing of selected pilot plants, and sketching the P&IDs). Interestingly, there was higher satisfaction with teamwork in P05 (32.2% Strongly Agree, 47.1% Agree) which came before P06 (28.7% Strongly Agree, 42.5% Agree). This could be due to the explicit instructions given to students in P05 (including how to use the jigsaw strategy), but we are largely silent on teamwork in P06. However, not being able to identify specific students who contributed to the survey questionnaire, which was conducted anonymously, we were not able to further link the negative findings from P05 (2.3% Strongly Disagree, 5.7% Disagree) and P06 (0.0% Strongly Disagree, 5.7% Disagree) with specific suggestions each student gave to team members in the 2 open-ended questions in the SPA/SAPA measurement.

Table 3. Selected Key Findings from Survey Questionnaire

Statement (Each statement had 5 possible answers, and each answer has a detailed description, that is for the purpose of this paper, had been broadly grouped into 3 categories of "Strongly Agree/Agree', 'Somewhat Neutral', and 'Strongly Disagree/Disagree')	Percentage of Responses		
	Strongly Agree or Agree	Somewhat Neutral	Strongly Disagree or Disagree
1. Do you find the activities in P05 sufficient put across the understanding of importance of self-directed learning (SDL), to help you make sense of a Piping & Instrumentation Diagram (P&ID) and the Lead Sheet?	58.6	36.8	4.5
2. Does the table-top line-tracing in P04 using a given P&ID and set of operating procedures, equipped you with the knowledge to prepare yourself for the actual work in the pilot plant itself?	75.9	23.0	1.1
3. Are you able to apply the skills in P&ID reading (covered in P05) and line-tracing (covered in P04) to the activities in P06 (i.e. line-tracing and sketching of P&ID pilot plant to be used in P7 to P10)?	81.6	18.4	0.0
4. Please rate how confident you are, envisioning in the near future, if you are in a new plant environment (for example during internship in Year 3) in your ability to read a P&ID of a chemical plant that is **new to you**; based on the skills acquired from P05 on P&ID Reading and Lead Sheet Symbols.	32.1	59.8	8.0
5. Do you think good teamwork (division of work, cross-teaching one another P&ID symbols for different categories of plant items, review of work done by each member, checking for completion of report before submission, etc) was practiced in the completion of the assignments required for P05 on P&ID Reading and Lead Sheet Symbols?	79.3	12.6	8.0
6. Do you think good teamwork was practiced in the completion of the assignments required for P06 on sketching of P&IDs for the assigned pilot plants – those to be used in later activities, namely P07 to P10?	71.2	23.0	5.7

Table 4. Sample Scoring for Teamwork Measurement

Class	Group A		Group B		Group C		Group D	
1B/0X	SPA	SAPA	SPA	SAPA	SPA	SAPA	SPA	SAPA
Student 1	0.99	1.00	0.93	1.02	1.08	0.92	1.05	0.94
Student 2	1.00	1.03	1.10	0.92	0.98	1.13	0.97	0.96
Student 3	1.00	0.89	1.10	1.05	1.00	0.90	1.00	1.11
Student 4	0.98	0.99	0.93	0.94	1.08	0.99	0.98	1.06
Student 5	1.03	1.01	0.99	0.95	0.85	0.80	1.00	1.00

The one challenge that we faced, in trying to discern the contributing factors that leads to the outliers, in particulars scores lower than 0.95, which can be sign of loafing or free-riding, is that students tended to be more 'conservative' when providing open-ended answers for their team members to improve, as compared to giving a score using Likert scales.

Lastly, it is to be noted that since not the entire 2 classes used the SPA/SAPA measurement to evaluate teamwork for this blended learning activity, we do not use the SPA scores for any mark adjustments.

REFLECTION ON THE LEARNING TASKS AND AREAS OF IMPROVEMENT

One of the main challenges that we tried to overcome using the blended learning approach is to provide students with realistic and immersive learning experience otherwise not available to them. Due to the large number of students (140 in total for Year 1), it is logistically not possible to arrange for visits to chemical plants. Even when visits are possible, the is a cap on the maximum number of students permitted on site, for example, a petrochemical company once restrict the trip to its premises to only 30 students. Even when a visit is possible, the trip is limited to a bus tour following prescribed lanes inside the chemical plant compound. There is in fact a legislation that all personnel must take a 1-day safety orientation course and pass its examination before one is permitted to enter *any* chemical plant. Therefore, there is no opportunities for students to get “up close” to a piece of plant equipment. Timing is also a factor, as a company can only host a visit for a duration of about 3 to 4 hours as the maximum.

With the COVID-19 pandemic, we faced additional challenges: first, the campus is closed for extended periods of time, and we need to convert as many experiments as possible to the “online” version. This unfortunately is not easily done for us in the chemical engineering discipline, as efforts are needed to create digital versions of pilot plants – both in terms of technical know-how to use the software and also the financial cost of doing so, in addition to the long development time. Second, even with the eventual opening of campus, and students are allowed back to the laboratory, the necessity of maintaining safe distance among students also imposed a constraint on how many of them can work in a given pilot plant. The COVID-19 pandemic had somewhat altered our plans on how to improve the student learning experience (CDIO Standard 12).

Moving ahead, the author is working on converting the activities in P04 and P06 (see Figure 1) into the e-learning version as well. It is envisioned that the design of P04 will use a combination of pre-recorded video of the Neutralizing Reactor Pilot Plant which is used for the activity; and pre-recorded, narrated PowerPoint slides. The Core Principles of Learning will once again the used, leveraging on learning acquired from P05 covered in this paper. In the author’s opinion, it is acceptable that this activity be fully e-learning, because the overriding consideration is to maintain safe distancing around a single pilot plant.

Lastly, is P06, for which the challenges students identified can best be addressed. Ironically, this is still be achieved with real presence in the pilot plant. Considerations for e-learning version of P06 however, is also more challenging in that this activity is meant to lead on to later activities, namely P07 to P10; which decidedly still requires physical presence at site working on the pilot plants. It is not expected that fully online versions of these activities will be available anytime in the near future. It is therefore decided to create a learning task based on Interactive Video for one of the four pilot plants for P07 to P10, namely the Shell-and-Tube Heat Exchanger Unit. Interactive video is a type of digital video that supports user interaction. These videos play like regular video files; but include clickable areas or "hotspots" that perform an action when you click on them. For example, when you click on a hotspot, a multiple-choice question may appear that require student response, or to display information about the object clicked on via a pop-up box, or to jump to a different part of the video, etc. The choice is made in order to retain some elements of interactivity that requires facilitation from the lecturer, to ensure that important learning points are covered, or highlight key features that may get glossed over by students, if they were left to complete the activity on their own.

While one can debate about the relative merits of going fully e-learning versus blended learning, notably in terms of full e-learning not being able to deliver certain desired learning outcomes that can only be developed or acquired via hands-on experience. This is especially the case for the chemical processing industries, where one also learns from the senses: sight, sound and smell; especially the latter that is hard to duplicate in the even with advanced technologies such as digital twin. Case in point is the radiant heat of a furnace, or the odour of fugitive emissions. The lesson of COVID-19 had in a way forced a decision on what matters most, in terms of continuity of some form of education via e-learning as compared to no learning at all due to campus closure. It had become more acceptable for lecturers to accept the fact that some learning outcomes need to be forfeited and replaced with less effective ones, e.g. verbal description or graphical depiction of unpleasantness of exposure to radiant heat or foul-smelling discharges.

All in all, it can be said that based on reports submitted by students (in terms of lead sheets, and sketched P&ID of various pilot plants), there had been improvements compared to previous cohort that learnt entirely through the face-to-face interactions. However, the author is hesitant to conclude from these observations alone, on effectiveness of blended learning, as there had been other improvements in the learning tasks implemented for this cohort with blended learning, such as the use workbook, or simply better design or presentation of the learning materials.

Lastly, on the teamwork measurement, as we ride on the institution-wide initiative for our own evaluation, we were not able to add additional questions to the standard template. This in the author's opinion, had somewhat limited the usefulness of the findings. Fortunately, he was able to build into the separate survey questionnaires, 2 questions that ask students for responses on their perception of teamwork when completing the blended learning activities (P05, P04 and P06) that enabled him to cross-check some of the findings reported by the SPA/SAPA calculations. Another point is that some authors highlighted on the needs for moderation of students' SPA/SAPA scores to account for possible biases among team members, or that some may try to game the results. The results obtained from this pilot run seemed to indicate that this is not a concern as far as the class is concerned. We need more trials with this way of measuring teamwork before a more affirmative decision can be made.

CONCLUSION

This paper shared the design of a blended format of integrated learning experiences for developing competency in P&ID reading using the Core Principles of Learning. Examples of how each of the ten core principles are explained and examples provided. Findings from students experience on the learning process showed that thoughtful design of such learning activities can benefit student learning. Preliminary results from the use of SPA and SAPA scores looked promising as a tool to assess teamwork, but more trials need to be used with more classes. Areas for improvement for the blended learning activities had been described, which pointed to the way for more online components to reflect the needs for continued delivery of education in the event of pandemic such as COVID-19.

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BIOGRAPHICAL INFORMATION

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TRANSFER OF SELF-DIRECTED LEARNING COMPETENCY

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ABSTRACT

In this new disrupted world, it is important for students to be self-directed learners and equipped with the ability to purposefully transfer their learning from one context to another. The Diploma in Chemical Engineering (DCHE) aims to develop self-directed learning (SDL) in students, and their ability to transfer learning by integrating SDL activities into different core modules of its 3-year curriculum. In this manner, students will develop SDL skills alongside other skills specified in those core modules. The general approach taken to integrate SDL into the DCHE curriculum, and how SDL was introduced in a Year 1, Semester 2 practical-based module through an explicit instructional process using the DCHE SDL Model supported by good thinking heuristics have been shared earlier. This paper continues with that study and determines if the same cohort of students, who had learnt SDL skills in Year 1, were able to apply them in later years of study to different contexts, specifically to a project-based module in Year 2, followed by internship at local companies in Year 3. Practical-based modules generally consist of structured workshop sessions with activities where application of SDL may not be so obvious or intuitive to students. Conversely, project-based modules, being less structured and often ambiguous, will naturally lead students to realise that SDL is necessary to complete their projects. This paper highlights the differences when embedding SDL into the different types of modules, then discusses the process of infusing SDL activities into the Year 2 project-based, chemical product design module by referring to the SP-customised CDIO syllabus. Simple surveys were conducted on the students to evaluate their ability to transfer the SDL skills learnt from the structured practical-based module in Year 1 and apply them to the project-based module in Year 2. The findings indicate that the students find the DCHE SDL Model useful in helping them learn systematically as they progress through the curriculum. There is also evidence of SDL transferability and application across the two years of studies and the different learning contexts. When a representative number of students from the same cohort were surveyed in Year 3 during their internship, findings show that they were also able to use the SDL skills acquired in school in the real-life work environment. The paper concludes by outlining areas of improvements to enhance transferability of SDL in DCHE students.

KEYWORDS

Chemical Engineering, Self-Directed Learning, Skills Transferability, Standards: 1, 2, 3, 11

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

INTRODUCTION

A key approach towards lifelong learning is to be self-directed (Candy, 1991; Alexander et al., 2004; Tunney and Bell, 2011; Weimer, 2015). A self-directed learner is able to identify one's own learning needs, set learning goals, manage his/her own learning, evaluate and fine-tune the learning process and subsequently extend (or transfer) his/her learning to different contexts and situations (Loyens et al., 2008). Transfer of learning, as defined by Brandsford et al. (1999) is "the ability to extend what has been learned in one context to a new context". As contexts progress from being similarly related to remotely related to each other, transfer of learning will also shift from one being instinctive and requiring minimal effort, to one that requires purposeful abstraction of concepts, effort to connect and apply to the different situations and reflective thinking (Dewitz and Graves, 2014). Transfer of learning is thus a complex process that is difficult to attain (Bereiter, 1995; Dewitz and Graves, 2014; Perkins and Salomon, 1988) particularly for more dissimilarly related contexts, but could be facilitated through the development of metacognitive skills (Belmont et al., 1982; Billing, 2007).

The Singapore Government launched the SkillsFuture Initiative in 2015 to help Singapore manufacturers remain competitive globally. A key thrust of the Initiative is to foster a lifelong learning culture. Singapore Polytechnic (SP) as an institute of higher learning, also recognises the importance of lifelong learning. A focus area of SP's new Educational Model is to prepare students to be lifelong learners by having self-directedness and the ability to transfer their learning so that they may be ready for uncertainties and challenges that await them.

THE SPIRAL CURRICULUM AND SELF-DIRECTED LEARNING IN DCHE

The Diploma in Chemical Engineering (DCHE) introduced its spiral curriculum course structure in 2018 (Cheah and Yang, 2018), which allows students to progressively develop the desired knowledge, skills and attitudes.

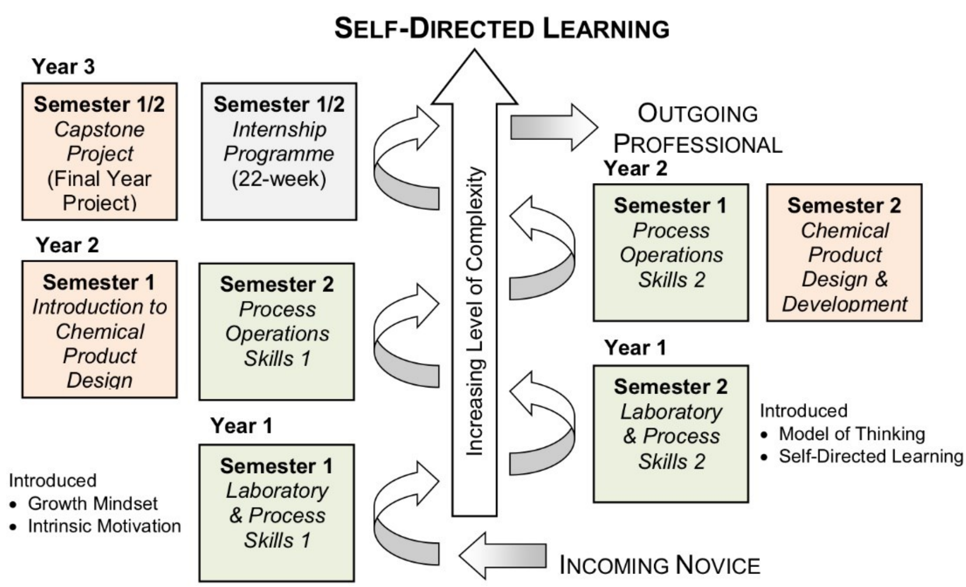

Figure 1. Progressive Development and Transfer of SDL Competency in DCHE

Self-directed learning (SDL) is integrated into the DCHE spiral curriculum through practical-based modules (Laboratory & Process Skills 1 and 2), as well as project-based modules (Introduction to Chemical Product Design, Chemical Product Design & Development and Capstone Project) as shown in Figure 1 (Cheah et al., 2019; Cheah and Chua, 2019). The intent is to gradually develop students' SDL competency in Year 3 to Advanced level, as defined in the lifelong learning generic skills and competencies under the SkillsFuture Initiative (Cheah, 2020), alongside other skills such as core technical skills.

To help students better understand the skills and attitudes of a self-directed learner, the DCHE SDL Model (Cheah and Chua, 2019) (Figure 2, left) was introduced to teach students the key steps in the SDL process in the Year 1, Semester 2 module, Laboratory & Process Skills 2 (Figure 1), with learning of metacognition supplemented through teaching of thinking heuristics using Sale's Model of Thinking (Sale, 2015) (Figure 2, right).

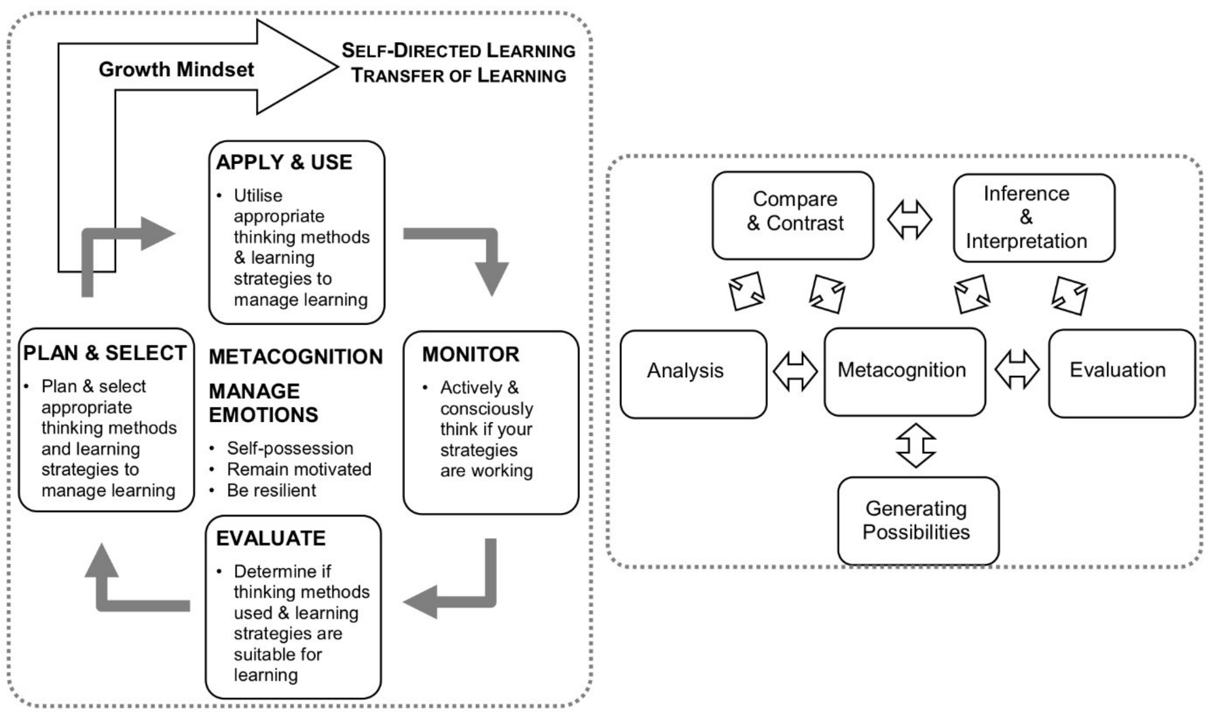

Figure 2. DCHE SDL Model (left) and Sale's Model of Thinking (right)

SDL scaffoldings and lecturer guidance are gradually reduced as students go through the curriculum, to progressively allow shifting of control and responsibility for learning to the students themselves, which, according to Azevedo et al. (2004) and Schunk and Rice (1993), is a truer hallmark of self-directedness and a more effective way for students to gain SDL skills. At the same time, they gain technical domain knowledge which increases their confidence to direct their own learning (Bolhuis, 2003; Grow, 1991). Growth mindset and metacognition, both important concepts in facilitating development of self-directedness and learning transfer, were incorporated into the DCHE SDL Model. Since continuous communication is one critical factor affecting transfer of learning (Cheng and Ho, 2001; Rossett, 1997), the rationale, purpose and benefits of the DCHE spiral curriculum and the various learning models embedded within, e.g. SDL, etc., were shared with students to help them understand and increase their acceptance and use of these learning models beyond the curriculum.

Evaluation of SDL in DCHE: A Longitudinal Study

Year 1 students in Academic Year 2018-2019 (AY1819) is the first cohort of students introduced to SDL. SDL is embedded in practical-based modules (Laboratory & Process Skills 1 and 2) in the context of laboratory investigative and process plant operation skills while SDL is incorporated in project-based modules (Introduction to Chemical Product Design and Chemical Product Design & Development) in relation to product design & development and C-D-I-O skills (Table 1).

Table 1. Development and Evaluation of SDL Skills in DCHE Students

Development of SDL Skills in DCHE							
DCHE Spiral Curriculum	**Academic Year**	**Year 1 Sequential**		**Year 2 Sequential**		**Year 3 Swapping**	
		Semester 1	**Semester 2**	**Semester 1**	**Semester 2**	**Semester 1/2**	**Semester 1/2**
	Module Name	**Laboratory & Process Skills 1**	**Laboratory & Process Skills 2**	**Introduction to Chemical Product Design**	**Chemical Product Design & Development**	**Capstone Project/ Internship**	**Internship/ Capstone Project**
Types of skills that are developed together with SDL Skills	Laboratory Investigative Skills (Bench-top)	✓	✓	N.A.	N.A.	✓	✓
	Process Plant Operation Skills (Pilot Plants)	N.A.	✓	N.A.	N.A.	N.A.	✓
	Product Design & Development C-D-I-O Skills	N.A.	N.A.	✓	✓	✓	✓
Evaluation of Student Experience in SDL							
SDL Implementation		**In-Campus**	**In-Campus**	**In-Campus**	**In-Campus**	**HBL (Circuit Breaker)***	**Mostly in-Campus**
Cohort AY1819 Pilot run to evaluate if students are able to transfer SDL skills learnt in one context to another		Students briefly introduced to Growth Mindset and SDL model	1st Survey on Experience in using SDL completed	2nd Survey on Experience in using SDL completed	1st Survey on Transfer to New Context completed	1st survey on experience & transfer during Internship completed	To survey on experience & transfer during Capstone Project

*Circuit Breaker (7 April 2020 – 1 June 2020) was a period where the Singapore Government implemented closure of non-essential workplaces and full home-based learning for schools to minimise the spread of COVID-19.

We conducted a 3-year longitudinal study to follow their progress for the entire duration of their study in the diploma to ascertain the effectiveness of the teaching of SDL, and to determine if they were able to demonstrate assimilation of knowledge and transfer it to new applications. More specifically, we were interested to find out if students were able to apply the SDL skills acquired in *one context* through the practical-based module, Laboratory & Process Skills 2, in Year 1 Semester 2, to a *different context* in the project-based module, Chemical Product Design & Development in Year 2 Semester 2 with progressively less scaffolding and guidance, and finally transfer and independently use the SDL skills in a real-world environment during their 22-week internship at a local company (in Year 3).

In Year 1 Semester 1, students were introduced to growth mindset in an activity in a practical-based module, Laboratory & Process Skills 1. In Year 1 Semester 2, students were taught the DCHE SDL model (Cheah et al., 2019) and Sale's Model of Thinking. Subsequently, they applied SDL in a series of workshops and some practical activities and performed reflective thinking to identify learning gaps that can be addressed by the SDL model. Most students found that the SDL Model was useful in helping them apply SDL (Cheah et al., 2019).

When the students progressed to Year 2 Semester 1, they revisited the Sale's Model of Thinking, DCHE SDL Model and growth mindset through three learning activities where they performed their needs analysis, ideation and preliminary design specifications for their chemical product in a project team setting in the Introduction to Chemical Product Design project-based module (Cheah and Chua, 2019). Since students were given full autonomy to decide on their chemical product idea, this translated to about 30 unique chemical product projects for the cohort. In Year 2 Semester 2, they continued to work on their chemical product ideas in another project-based module, Chemical Product Design & Development. In the same project team, they had to manage the construction and testing of their chemical product prototype, and communicate the work done, the design approach, design process and prototype testing results, through a design portfolio to the facilitator.

We referred to the SP-customised CDIO syllabus, specifically sections 2.4.5 *Demonstrate Metacognition and Knowledge Integration,* 2.4.6 *Engage in Lifelong learning (Self-directed Learning)* and 2.4.7 *Manage Time and Resources* to guide us in designing SDL-infused learning activities related to the management of their chemical product projects so that students could apply SDL skills learnt earlier in structured learning activities to this new, ambiguous context of managing a project. Infusing SDL activities into project management also allowed these activities to be done by all students regardless of the type of project they had. We also reduced the amount of scaffolding and provided only the DCHE SDL model and limited guidance questions to students for them to apply the SDL model when they create a Gantt chart to manage their project (Table 2). Compared to the two Year 1 practical-based modules, Laboratory & Process Skills 1 and 2, and the project-based module in Year 2 Semester 1, Introduction to Chemical Product Design, the guidance questions on metacognition and managing emotions were embedded in all 4 SDL stages as students were expected to think about their own thinking, and manage their emotions throughout at this juncture.

Table 2. Examples of SDL Guidance Questions in Chemical Product Design & Development

Stages of SDL		**Examples of Guidance Questions**
Metacognition Manage Emotions	Plan & Select	What is the importance of project management? What are the deliverables of the Project Management activity? Are we doing Project Management activity only to get the marks? By when must we complete Project Management activity - Is the time given sufficient, if not, what can we do? What are the project management tools at our disposal? Do I know how to apply the project management tools - if I am not sure, what help or resources can I fall back on? How detailed or broken down should the list of project tasks be to be reasonably practicable? Should the team discuss it or seek advices from the facilitator or both?
	Apply & Use	For the purchases of materials to construct a prototype, do we give a slightly longer duration in anticipation of delays in deliveries? Perhaps even a longer duration if we buy from an overseas supplier? Our team is given 3 weeks to construct and test our product prototype - how should we schedule the work? To ensure the schedule feasibility, what are the tasks that can be carried out concurrently to save time but carrying out tasks concurrently also means manpower will be split, do we have the bandwidth to operate? How do we do the tasks distribution to achieve fairness and manage emotions of all team members?
	Monitor & Evaluate	Is the information contained in the Activity Logic Table correct and practical? Is the information in the Activity Logic Table correctly transposed to Network Diagram, and then the Gantt chart? Have we examined the work thoroughly? Did we leave out anything important? We can probably exchange views with other teams - they may see things that we do not? Does the project meet the schedule feasibility – if not, what can we do? How regular should the Gantt chart be updated? Who is responsible for updating it?

After two years of practising SDL in the school curriculum, students moved onto their internship in Year 3 in a real-world work place environment where they would have to deal with unfamiliar processes with little or no supervision from their lecturers. Although students were allocated a company supervisor for the duration of the internship, level of supervision provided will vary based on factors such as company culture and the supervisor's personality. Students would also have to complete an individual project on top of their daily work tasks at the workplace. Internship was therefore the most opportune time for them to independently apply their technical knowledge and use the SDL skills acquired to help them overcome challenges faced.

We report on the students' SDL learning experience in Year 2 and their experience in using SDL during their internship in Year 3 in the next section. We surveyed the students' experience in using the DCHE SDL Model when they were in Year 2 to see if there was a difference when the learning context changed from practical-based activities and workshops to project-based chemical product design. We also surveyed the students on their learning experiences in Year 2 Semester 2 in the Chemical Product Design & Development module itself, and also in Year 3 during their internship and Capstone Project to check for evidence of transferability. The cohort of students was split in Year 3. In Semester 1, half of them went on internship and the other half remained on campus for their Capstone Project. The students will then do a swap in Semester 2. The findings on the students' experience in using SDL during the Capstone Project in Year 3 is not within the scope of this paper and will not be discussed here.

RESULTS AND DISCUSSION

Student's Experience in using DCHE SDL Model

Students continued to find the DCHE SDL Model useful in helping them learn systematically as they progressed through the curriculum, from Year 1 to Year 2 (Figure 3).

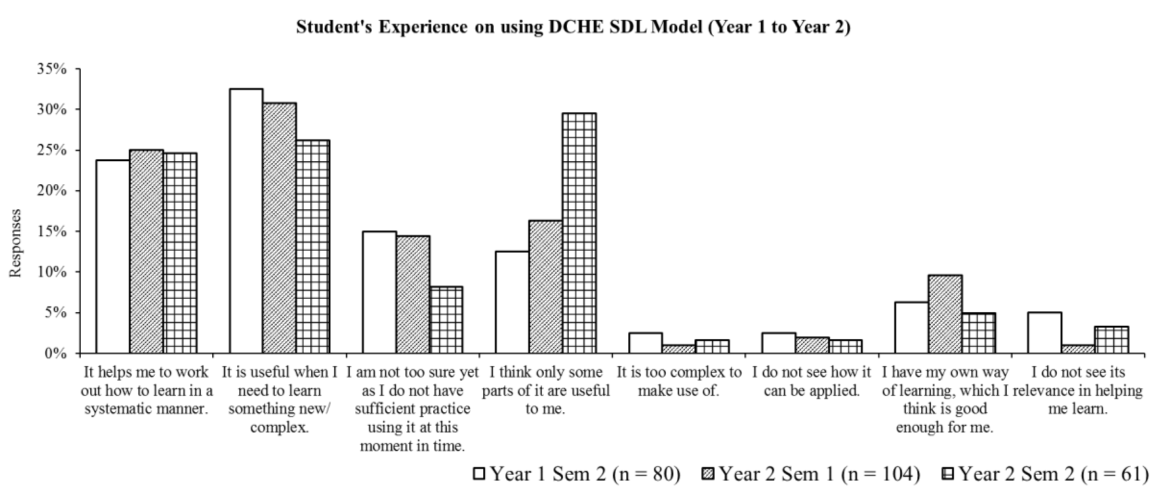

Figure 3. Students' Experience on using the DCHE SDL Model

It is also worth noting that students found the DCHE SDL Model useful when they needed to learn something new and complex. Gureckis and Markant (2012) opined that SDL helps optimise one's learning experience, allowing the student to focus on useful information that he/she does not already possess and exposing him/her to information that he/she does not have access to through passive observation. This content curation and analytical skill is important when one is learning something new or complex, and the DCHE SDL Model and Sale's Model of Thinking offer that. As they gained more practice in using SDL, they become more familiarised with SDL, similar to the observation made by Van Woezik et al. (2019) who found that students need to be given time to familiarise themselves with a new mode of learning. Furthermore, when students apply SDL, he/she also gets to learn other important skills such as time management, self-assessment and goal setting. These are important skills that can be applied anywhere, across contexts.

Transferability of SDL – Chemical Product Design Project

When students worked on their chemical product design project in Year 2 Semester 2, they were expected to run their own project by managing critical project tasks, from creating and refining a bill of materials for a chemical product prototype, procuring materials needed, conducting a risk assessment on prototyping activities, to constructing and testing the chemical product prototype, preparing a design portfolio and monitoring project progress using a Gantt chart. All these naturally requires students to be self-directed. As such, we believe project management is a good platform to allow students to apply and reinforce their SDL skills, consistent with what was reported by Eggermont et al. (2015).

In the management of the chemical product design project, students were given less scaffolding to guide them in applying SDL in a context different from what they had encountered before. This progressive withdrawal of scaffolding is consistent with the model proposed by English and Kitsantas (2013), in which teachers begin with a high-level of teacher directions and then gradually remove the scaffolds so that students will increasingly take ownership of their learning.

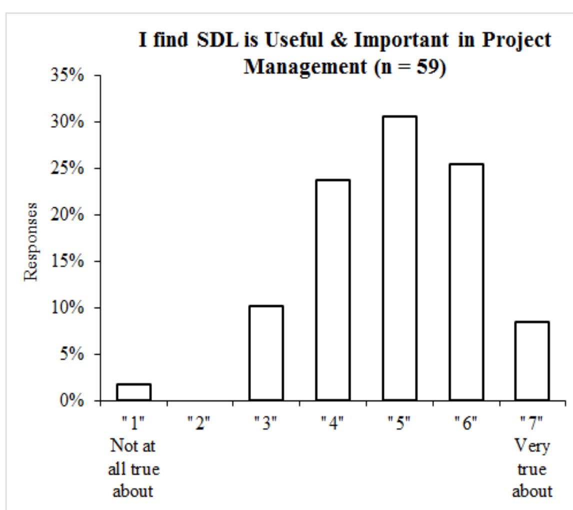

Figure 4. Students' Responses on Usefulness & Importance of SDL in Project Management

64.4% (only favourable responses were considered, i.e. those of "5", "6" and "7") of the students (Figure 4) found that SDL was useful and important in managing a project although they had only previously applied SDL to structured learning activities. This observation is shared by Johnson et al. (2015), who wrote about the usefulness of project-based learning in teaching students SDL skills.

When polled, nearly 50% of the students expressed that they did make use of the set of curated SDL guidance questions in managing their chemical product design project (Table 2), suggesting that the guidance questions remained relevant and useful, similar to that reported by Perkins and Salmon (1988) who suggested that explicit instructions would be helpful for students to transfer their learning from the original context to a new context. A third of the students however confessed that they did not use the guidance questions. This could mean that the students either did not require scaffolding for SDL as they already had 3 semesters of prior experiences and practice, similar to that observed by others (Azevedo et al., 2004; Schunk and Rice, 1993), or they were not able to apply SDL to project management. One possible reason for students not being able to apply SDL could be related to their level of readiness. Stewart (2007) shows that SDL readiness is a key enabler for achieving learning outcomes from project-based learning, which is often open-ended, ambiguous and requires knowledge beyond the curriculum. If students are not ready to take control and responsibility for their own learning, they most probably will not learn SDL and apply it (Brockett and Hiemstra, 1991; Candy, 1991), or will resist its use.

Perkins and Salomon (1988) reported that transfer of learning requires one to be able to refer back to the context where the learning had taken place originally and find similarities to connect the learning to the new context where the learning has to be transferred. This process becomes increasingly more difficult and requires more metacognition and motivation as the new context becomes increasingly dissimilar to the original context where learning had occurred.

Therefore, when slightly more than half of the students (53.3%) found their prior SDL experiences useful when they had to apply SDL in a new context to manage their chemical product design project, this suggests these students were able to transfer their learning from the practical-based module, Laboratory and Process Skills 2 to the project-based module, Chemical Product Design and Development.

Transferability of SDL – Internship

When students progress to Year 3, the cohort will be split, with half the cohort undergoing a 22-week internship at a local company and the other half remaining on campus to complete their capstone project first, after which they will swap (see Figure 1 and Table 1).

Students on internship have to complete the individual graded internship project whilst fulfilling their daily work requirements at the company. Compared to the student-initiated, group-based chemical product design project done in Year 2, students on internship had little to no autonomy to decide on the type and scope of their projects, and the project methodology as these were predominantly specified by the companies. Outcomes from the chemical product design project also only contributed to the wider knowledge base while that from the internship projects had specific value to the company and often had to be solutions to real-life problems faced by the company. Since the internship project is company-specific, and our students are placed in companies whose nature range from manufacturing, testing, to research and development, their projects will reflect this varied nature of placement and the 3-year curriculum will not likely cover the needs of all companies that our students intern at. Students are thus expected to use SDL skills to manage and at the same time learn the new materials needed to complete their internship projects.

Application of SDL was evident when we surveyed the same students who completed their local internship in Year 3. For half the cohort who did their internship in Semester 1, 16 out of 30 respondents (53.3%) expressed that they had to learn new materials for work on their own.

This is similar to the other half of the cohort who completed their internship in Semester 2. 23 out of 38 respondents (60.5%) indicated that they too had to learn new materials independently. Although there exists external factors, such as limited supervision, that will inadvertently led students to be more self-directed during their internship than compared to when they were in the school environment, all students except for one student, who had to learn new materials independently during internship agreed that SDL skills acquired in school were useful for their internship. The respondent who disagreed stated that he/she did not know how to use the skills during internship as he/she did not remember the steps to do so. Interestingly, a follow up question posed to that respondent revealed that he/she had actually applied the SDL skills acquired in school during internship; he/she had planned his/her own work, identified gaps and the resources needed to bridge the gaps in his/her knowledge to achieve his/her goal.

Students who have already been thinking about their own thinking, essentially the application of metacognition, will find it easier to make the transfer successfully (Belmont et al., 1982; Billing, 2007). Since these students were also taught metacognition through the Sale's Model of Thinking, they would find it easier to make the transfer, as evidenced by the students' responses when they were asked about their learning and applying new things at the work place in Year 3 (Figure 5, n = 16 (Semester 1), n = 23 (Semester 2) for students who had to learn new things on their own). The questions asked are as indicated in Figure 5. It is worthwhile to note that the data in Figure 5 may not be representative given the small sample sizes.

Most students indicated they were able to identify their own learning needs, plan, monitor and evaluate their own learning while managing their emotions at work. They essentially displayed characteristics of a self-directed learner who had transferred what they learnt about SDL, from structured activities to projects in the school, and eventually to real-world work places. This shows that the students were able to transfer SDL competency successfully during their internship in Year 3.

Overall Discussion

One of the challenges that arose during this process to develop DCHE students into self-directed learners through the infusion of SDL into the DCHE curriculum is to balance the amount of guidance and feedback students receive and the level of independence students can be given over what they learn so that they can become self-directed learners. This is a similar observation made by others (Shanley, 2007; Dorna et al. 2007). Our students come from diverse socioeconomic backgrounds, and to a certain extent, possess varied academic abilities and different levels of interest in the course. Being new to the course, they will not have the technical domain knowledge hence may lack confidence in their own abilities to complete new learning tasks in Year 1. They are also used to be passive learners as moulded by the traditional education methods prior to entering SP. As such, they will hesitate to take control and responsibility for their learning, preferring instead for their lecturers to do so (Van Woezik et al., 2019). Having different levels of interest in the course will also influence their emotional and mental investments in learning tasks. This in turn will affect the extent to which they will explore and eventually adopt the use of SDL in their learning (Maiese, 2017) and to transfer it to an entirely different context. There is a need to calibrate the level of lecturer guidance and feedback to give students just enough support so that they will be encouraged to persevere in using SDL, and eventually gain confidence to take control and responsibility for their own learning.

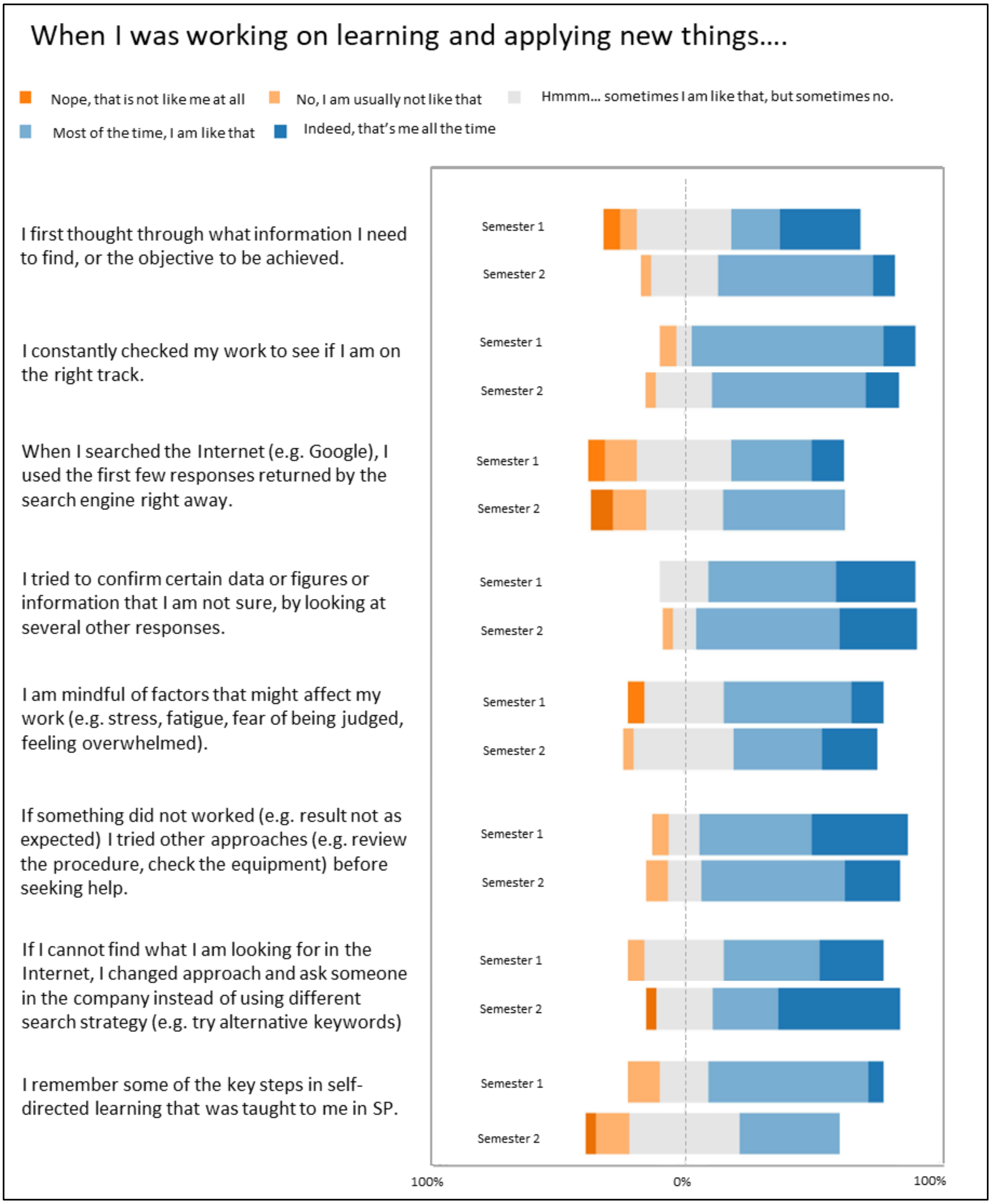

Figure 5. Students' Responses when Learning and Applying New Things during Internship

Based on the results obtained so far, we are encouraged that students seemed able to practise and use the SDL skills taught in Year 1, Semester 1 in different contexts in the familiar school environment where guidance from lecturers was still available. They also seemed to have developed into self-directed learners during their internship at a real-world work environment, after two years of practising SDL and gaining familiarity with its use in different contexts.

CONCLUSION

This paper reported the work done for only one cohort of students, which did not allow for statistical analyses. The results show that the students were able to transfer SDL skills learnt in one module and one context to another as they progress through the DCHE spiral curriculum, and then to the real-world work environment during their internship. Moving ahead, we have plans to convert some Year 1 practical-based modules to e-versions and continue to study how to develop SDL and enhance its transferability in DCHE students.

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ENHANCING WORKPLACE LEARNING THROUGH STRUCTURED INTERNSHIP

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ABSTRACT

Internship has been an integral part of engineering education globally to develop proficiency in professional knowledge and skills, as well as personal and interpersonal skills. The integrated learning experiences provided by internship helps to foster learner's disciplinary knowledge, critical thinking, problem solving, teamwork and communication skills. Internship provides opportunity for learners to work on conceiving, designing, implementing, and operating (CDIO) engineering systems in a real-world context. In Nanyang Polytechnic (NYP), internship is offered to all year-3 learners at the School of Engineering (SEG). There are two types of internship programmes, one with a duration of 12 weeks and the other with a duration of 24 weeks, and learners can carry out their internship in local or overseas companies or institutions. The Internship Framework at NYP undergone a major revamp to introduce Structured Internship in 2015. With this revision, a new set of clear and relevant learning outcomes were defined for the structured internship programmes. More 24-week internships were allocated for industry sectors requiring deeper technical expertise to be developed, and interns could benefit from structures workplace learning and project assignments. A study was conducted in year 2020 to evaluate the effectiveness of the revised internship framework, as well as to identify key internship design characteristics that enhance workplace learning. The results of the findings depict that the workplace learning experience has improved significantly since the revision, and that longer internship duration does enhance the intrinsic motivation of our learners. Graduate employment surveys conducted have also shown that workplace experience gained during structured internship has been useful for work and life after graduation. The study also identified top four factors impacting the success of structured internship, and they are "Able to learn and apply technical and soft skills," "People they worked with," "Task assigned is achievable" and "Industry Internship Mentor" respectively.

KEYWORDS

CDIO, Internship Design, Integrated Learning, Workplace Learning Experience, Intrinsic Motivation.

INTRODUCTION

Internship has been an integral part of the engineering courses offered by the School of Engineering (SEG), at Nanyang Polytechnic (NYP) since its establishment in 1992. In SEG, all learners go through a 12-week full-time internship programme during the third year of their studies, aimed at providing opportunities for learners to gain workplace experience and to prepare them for employment. In 2014, an Applied Study in Polytechnic and ITE (ASPIRE) was conducted by the Ministry of Education Singapore. It led to the establishment of SkillsFuture Singapore with the mission to build a future based on skills and mastery. Following on the recommendations made by ASPIRE, a few major changes were proposed to the curriculum of the diplomas offered by the polytechnics. Two of these changes were the structured internship and the education & career guidance. The structured internship is the focus of this paper.

With the introduction of the structured internship, major revisions were made to the existing internship programme so that new elements could be introduced. The key elements that are introduced include more detailed learning outcomes covering key objectives of the structured internship, internship scopes that are coherent with the intended learning outcomes, use of assessment rubrics that are aligned with the learning outcomes, pre-internship briefing and post-internship review, and well-defined guides for School Internship Mentors (SIM) and Industry Internship Mentors (IIM). Along with these proposed elements, there was also recommendation to lengthen the duration of the internship. The following sections cover the design, development, implementation, and review of the Enhanced Internship Framework that NYP has introduced in 2015 to meet the structured internship requirements.

Enhanced Internship Framework (EIF)

Two base models were proposed in EIF to provide basic guidelines in internship design. Base model 1 is a combination of a 12-week Internship (ITP-12) and a 12-week Final Year Project (FYP) Work. Base model 2 is a 24-week Internship (ITP-24) with substantial amount of project-based learning. Both ITP-12 and ITP-24 provide an avenue and opportunity for learners to work with the industry on projects mutually agreed upon by the company and SEG. Learners will carry out their projects at the company. In addition to enhancing technical knowhow and skills in project development, learners will have the opportunity to develop other important workplace skills such as positive working attitude, personal and interpersonal skills, and communication skills. Learners will also be able to gain industry experience and appreciate the challenges of working on projects with real-life constraints. The introduction of a longer internship (ITP-24) was meant for industry requiring deep technical expertise that could better be developed through meaningful workplace training, assignments, and experience.

Learning Outcomes

The objectives of the structured internship are to provide a real-life work environment to facilitate a structured and integrated learning experience for the learners. This will enhance their learning by applying the knowledge and skills gained during the course work to work practice. By working on real-life scenario, the learners will be able to deepen relevant skills as well as gain broader perspective and knowledge of the industry, companies and professions, work value and culture, so that they are better prepared to pursue a career in their field of studies. With these objectives in mind and using CDIO Syllabus as a guidance, SEG has developed a set of learning outcomes (LO) to be achieved at the end of the internship programme. Table 1 lists the LOs for the structured internship, with mapping to the updated CDIO 2.0 syllabus (Crawley, Malmqvist, Lucas and Brodeur, 2011.)

Table 1. Mapping of LOs to CDIO 2.0 Syllabus

S/N	Learning Outcomes	CDIO Syllabus
1	Demonstrate the application of knowledge and skill sets acquired from the studied course and workplace in the assigned job function(s)	2.1.1 Problem Identification and Formulation 2.1.4 Analysis with Uncertainty 2.1.5 Solution and Recommendation 4.3.4 Development Project Management 4.4.1 The Design Process 4.4.3 Utilization of Knowledge in Design 4.5.1 Designing a Sustainable Implementation Process 4.5.2 Hardware Manufacturing Process 4.5.3 Software Implementing Process 4.5.4 Hardware Software Integration 4.5.5 Test, Verification, Validation, and Certification 4.5.6 Implementation Management 4.6.1 Designing and Optimizing Sustainable and Safe Operations 4.6.2 Training and Operations 4.6.3 Supporting the System Life Cycle 4.6.4 System Improvement and Evolution
2	Solve real life challenges in workplaces by analysing the work environment and conditions, and selecting appropriate skill sets acquired from course of study	
3	Articulate career options by considering opportunities in the company, sector, and industry for professional and educational advancement	2.5.3 Proactively Vision and Intention in Life 2.5.4 Staying Current on World of Engineering
4	Communicate and collaborate effectively and appropriately with different professionals in the work environment through written and oral means	3.2.1 Communications Strategy 3.2.2 Communications Structure 3.2.3 Written Communication 3.2.4 Electronic / Multimedia Communication 3.2.5 Graphical Communication 3.2.6 Oral Presentation 3.2.7 Inquiry, Listening and Dialog
5	Exhibit critical thinking and problem-solving skills by analysing underlying issue(s) to challenges	2.4.1 Initiative and Willingness to Make Decisions in the Face of Uncertainty 2.4.2 Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility 2.4.3 Creative Thinking 2.4.4 Critical Thinking 2.4.5 Self-awareness, Metacognition and Knowledge Integration 2.4.6 Lifelong Learning and Educating 2.4.7 Time and Resource Management
6	Demonstrate the ability to harness resources by analysing challenges and considering opportunities	
7	Recommend ideas to improve work effectiveness and efficiency by analysing challenges and considering viable options	
8	Demonstrate appreciation and respect for diverse groups of professionals by engaging harmoniously with different company stakeholders (e.g., colleagues, supervisors, suppliers etc.)	2.5.1 Change to Ethics, Integrity, and Social Responsibility 2.5.2 Professional Behaviour 2.5.5 Equity and Diversity
9	Exhibit professional ethics at work	

Assessment

An important consideration when designing the structured internship programme is to ensure assessments and instructional strategies are aligned with the LOs (Biggs & Tang, 2011; Maki, 2010). During the internship, learners are assessed by both the IIM and the SIM based on their workplace learning and tasks performance, their documentation of work log, as well as their reflection of the tasks completed. In assessing learners' workplace performance, the criteria used in the rubric include work ethics and professionalism, professional proficiency, quality of works and work outcomes, communication and teamwork, and independent learning skills. At the end of the internship, learners will have to make a presentation on the outcomes of their internship to an assessment panel, and to submit a written report on the work or tasks completed during their internship. The criteria used in the rubric to assess learner's internship report are organization, content, quality of writing and reflection on the internship, while the criteria used for assessing presentation are organisation & content, presentation skills and ability to answer questions.

Implementation

A series of communication channels and platforms were instituted to ensure the objectives of the enhanced internship programme were communicated clearly to the stakeholders. For instance, an IIM guide was developed to explain the objectives of the structured internship, the need to provide a structured training to interns, the assessment framework which include the assessment plan, criteria and rubrics, and the feedback mechanisms. A similar guide was also developed for the SIM for them to work closely with IIM. Briefing is conducted for learners one week before they start the internship. The briefing aims to provide opportunity for the learners to clarify any concerns regarding internship, and to motivate them to make the best use of workplace learning opportunity provided by the hosting companies.

Evaluation

At the end of the internship, interns are encouraged to provide feedback in the form of survey for programme evaluation. The survey gathers feedback on the LOs, workload, assessment, equipment or facilities, SIM, IIM, as well as overall workplace learning experience. IIMs are also encouraged to provide feedback through the internship evaluation form. Feedback from IIMs are sought in the areas of internship duration, scope of learning outcomes, operational effectiveness and efficiency, and areas for improvement.

BACKGROUND

Literature review

A study conducted by James (2018) on benefits of mandatory internship has shown that internship better prepare learners in career skills, such as problem solving, networking, oral presentation, interpersonal communication, among others. The top 4 substantial benefits interns gained were Experience (gain hands-on/real world/relevant experience), Career (clarity, exposure, security, and success), Networking (made connections, gained references, built network in industry), and Increased industry awareness. Rouvrais et al. (2020) shared that having workplace learning during internship permits learners to apply their knowledge and skills in real contexts, in non-simulated environments, and thus develop real professional competencies. They have also suggested an extension to the CDIO framework to systematically include work-based learning as integrated activities to better match industry's requirements as well as learner's competency when they work as engineer upon graduation. Johari & Bradshaw (2008) shared in their study on employing Project-based Learning in internship, concluded that tasks assigned should be collaborative and doable but challenging, not too complex, and offer choices. In addition, the roles of mentor were equally important; other than providing encouraging feedback, the role of mentor largely involves facilitation, monitoring learning processes, and gradually releasing learning responsibilities to the interns. Kamp & Verdegaal (2015) on a separate study found that the main motivational factors in internship, based on learner's perspective, were gaining personal and interpersonal skills and engineering capabilities, such as employability, preparing for job interviews and writing application letters, giving tools how to approach and apply, among others.

Preliminary Observation on Structured Internship

Knowing the importance of workplace learning as well as key factors impacting workplace learning experience from the literature review, the aims of this study were to establish evidence that the introduction of structured internship does produce outcomes that are aligned to these review findings. In fact, with the introduction of EIF since 2015, two positive trends were already observed. First observation was that learner's performance in internship modules was generally better than most of the other academic modules. Second observation was that more learners were opting for 24-week internship instead of the hybrid model of Internship (12-week) and Final Year Project work(12-week). This second trend is shown in Figure 1 where the percentage of learners opting for ITP-24 has increased from 25.7% in 2016 to about 41% in 2019.

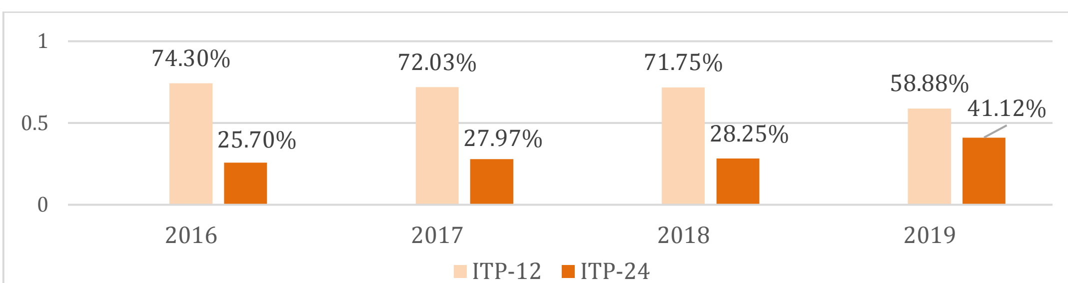

Figure 1. Distribution of 12-week Internship and 24-week Internship

In discussion with the course management teams, they opined that learners are motivated to perform well due to grading of internship modules. Learners strife to perform better to obtain good grades so that they have higher chances to be enrolled into reputable universities or to qualify for distinguished scholarship or awards. A follow-up focus group discussion with some learners was conducted, they fed back interest in engineering careers was higher after their internships. This finding suggests that learners could have opted for the ITP-24 due to module grading, but interest in engineering field was gradually built up during their internships.

Research Questions

This study sets to, firstly to establish evidence that learners are gaining better workplace learning experience through the introduction of structured internship. Secondly, the study aims to establish evidence that longer internship duration (ITP-24) does nurture higher interest in engineering fields to learners as compared to ITP-12. This finding is important as learners with intrinsic motivation toward a certain engineering field would have more sustainable interest and hence be able to learn at an optimal level and acquire important workplace knowledge and skills during their internship. Thirdly, the study aims to establish important internship design characteristics that lead to successful workplace learning for our learners.

METHODS

The effectiveness of the structured internship programme is evaluated using the data gathered from two survey mechanisms put in place. One of them is the module feedback survey that is administered to all learners at the end of the internship each semester. The learners' responses on "Overall experience gained is useful and relevant" are used as the indicator on workplace learning experience. The survey uses a Likert Scale of 1 to 4, 1 being "Strongly Disagree" and 4 being "Strongly Agree". A second mechanism is based on graduate employment survey, which is conducted six months after learners graduated from the Polytechnic. Graduates can feedback if they have gained useful work experience from the internship by indicating one of the following responses: "Strongly Agree", "Agree", "Disagree" or "Strongly Disagree".

In addition, the Intrinsic Motivational Inventory (IMI) Questionnaire is adopted in this study to evaluate the impact of internship duration on learner's intrinsic motivation. This survey consists of 20 questions covering 5 subscales defined in the original IMI questionnaire, namely "Interest" (4 questions), "Perceived Competence" (4 questions), "Usefulness" (5 questions), "Relatedness" (4 questions), and "Effort" (3 questions), using a Likert Scale of 1 to 7. The "Interest" subscale is a self-report measure of a person's liking towards the tasks given; the "Perceived Competence" subscale refers to a person's perceived ability to carry out the tasks given; the "Effort" subscale refers to the how much effort a person is willing to put in to carry out the tasks; the "Usefulness" subscale refers to how a person find the tasks and experience useful or valuable; and the "Relatedness" subscale is used in studies having to do with interpersonal interactions, friendship formation, etc. Within this survey, an additional question is added for learners to provide input on the top three factors that have positive impact on their internship. There were 9 options provided, and an open-ended space for learners to provide any other factor that they deemed important to the success of their internships. This survey was administered to 120 learners from 4 randomly chosen diplomas in SEG in year 2020 using a Google survey form at the point when this study was conducted. As a follow up from the survey, 10 learners from the 4 diplomas were invited to participate in an interview. Semi-structured questions that focus on internship design elements that impact their workplace learning experience were used to gather additional views and opinions from the learners. Learners were interviewed individually after their internship. Their feedbacks were analysed manually, to find the underlying reasons, views, and factors affecting internship experience.

RESULTS

Internship Module Feedback

Table 2 shows that the overall internship experience extracted from 2015 to 2018 feedback data. Learners reported an average score 3.49 with a standard deviation of 0.22 on a Likert Scale of 1 to 4 in 2018, as compared to an average score of 3.25 with standard deviation of 0.18 in 2015. The data shows that their experience has improved over the last 4 years, since the introduction of the structured internship.

Table 2. Workplace Experience Feedback Score

	2015	*2016*	*2017*	*2018*
Mean	3.25	3.41	3.48	3.49
Median	3.29	3.38	3.41	3.43
Standard Deviation	0.18	0.25	0.21	0.22
No. of learners	1109	1140	1230	1154

Graduate Survey on Internship

Result from an analysis on the graduate employment survey data between 2018 and 2020 for all engineering graduates is shown in the Figure 2. The percentage of graduates who acknowledged that they had gained useful work experience during internship, i.e., those who had responded as "Strongly Agree" and "Agree"), has improved over the last three years, from 82.11% in 2018, to slightly above 88% in 2020.

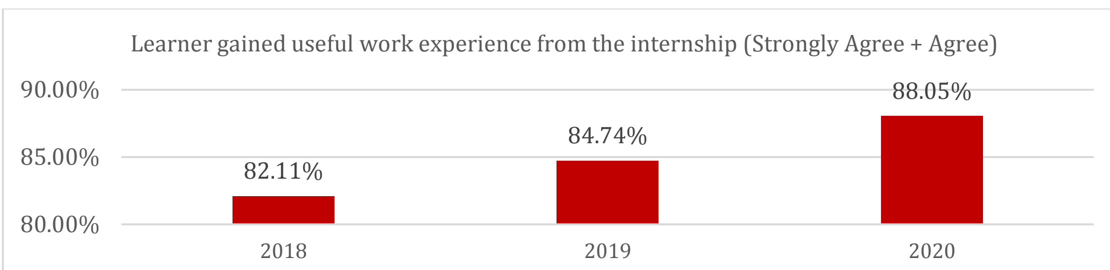

Figure 2. Graduates' response on gaining useful work experience during internship

Intrinsic Motivation Inventory Survey

For the IMI survey adopted and posted, a total of 108 responses were received from learners coming from Biomedical Engineering, Nanotechnology and Materials, Electronics System and Electrical Engineering with Eco-Design. Of these learners, 63 and 45 completed their ITP-12 and ITP-24 respectively. Table 3 shows the results of the IMI Survey. A t-test was conducted to compare learner's intrinsic motivation in 5 subscales, the result shows that except for "Relatedness", ITP-24 is statistically significant ($p < 0.05$) on all the 4 subscales, "Interest", "Competence", "Usefulness" and "Effort", as compared to ITP-12. The effect size (Cohen's D) for the following 4 subscales is high: Interest: 0.3782, Competence: 0.3697, Usefulness: 0.3436, Effort: 0.2911), indicating nontrivial effect. However, the effect size for "Relatedness" is 0.18, indicating a trivial effect. The "Relatedness" subscale is used in studies on interpersonal interactions, friendship formation, etc. In our context, it refers to the relationship between the interns and their mentors, supervisors, or co-workers from the hosting companies. This result depicts that longer internship duration does increase learner's intrinsic motivation.

Table 3. Results of t-test on Intrinsic Motivation Survey

	Interest		**Competence**		**Usefulness**		**Relatedness**		**Effort**	
Internship	ITP-12	ITP-24	ITP-12	ITP-24	ITP-12	ITP-24	ITP-12	ITP-24	ITP-12	ITP-24
Mean	5.30	5.87	5.20	5.68	6.07	6.45	5.76	6.01	5.94	6.27
Variance	2.42	2.00	1.86	1.44	1.28	1.11	1.97	2.25	1.56	0.79
P(T<=t)	0.0001		0.0002		0.0001		0.0761		0.0110	
Cohen's D	0.3782		0.3697		0.3436		0.1753		0.2911	

The results of the additional survey question on factors impacting the success of internship are shown in Figure 3. It is observed that higher percentage of learners completed ITP-24 cited that the two factors: “Industry Internship Mentor (IIM)” and “able to learn and apply technical and soft skills” played an important part for the success of their 24-week internship, as compared to those learners who completed ITP-12 (> 5%). On the other hand, learners completed ITP-12 felt that “Stipend” was important to them as compared to those learners who completed ITP-24 (> 4%). For the rest of the factors, it is observed that there is no significant difference between percentages in ITP-12 and ITP-24.

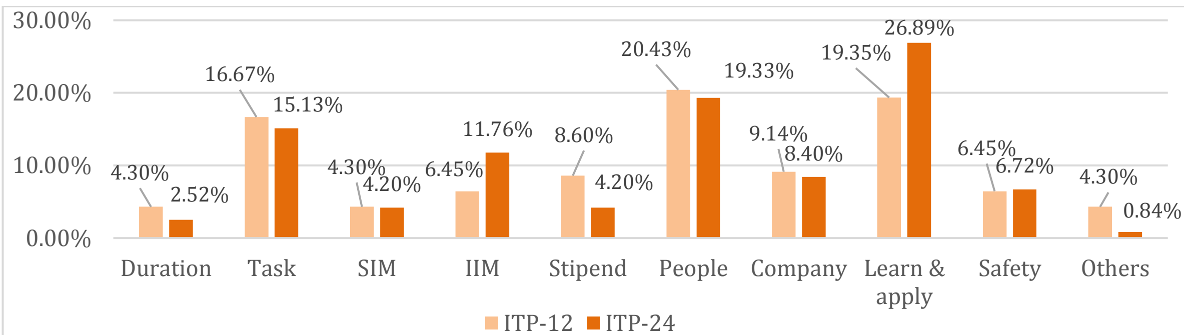

Figure 3. Factors Impacting Workplace Learning in ITP-12 and ITP-24

Individual Interview

The purpose of the individual interview is to explain and refine the survey results obtained from quantitative data analysis. A total of 10 learners who participated in the IMI survey, agree to, and attended the interview. Out of these interns, 7 have completed ITP-24 and the remaining 3 completed ITP-12. In this interview, the aim is to find out the reasons for the top 4 factors being selected as key to the success of their internships, namely “Able to learn and apply technical and soft skills,” “People they worked with,” “Task assigned is achievable” and “Industry Internship Mentor” respectively. Content analysis is usually used to analyse responses from interviewees. Content analysis is a research tool used to determine the presence of certain words, themes, or concepts within the given qualitative data (i.e., text). Using content analysis, researchers can quantify and analyse the presence, meanings and relationships of such words, themes, or concepts. Content analysis was used to analyse responses from the 10 interns.

After completing the coding, the results showed that most of the learners felt that the ability to learn new knowledge and apply them successfully would determine how well they performed in the company, and hence impacted the outcomes of their internships. They also felt that their success depended significantly on the availability of the supervisors or mentors in guiding them, in encouraging them, and in training them on the tasks assigned during the internships, which would directly impact the successful completion of their internships too. The results further showed that the tasks assigned should be achievable, and not something which were too routine and mundane, or something beyond what they were capable of doing. These observations reiterate the important design attributes of a successful internship.

CONCLUSION

The structured internship introduced in 2015 with the objective to enhance workplace learning experience, has been validated in this study. With the introduction of EIF, where several changes have been put in place, including grading and assessment methods, longer internship duration with establishment of SIM and IIM to guide and mentor the learners, the workplace learning experience has improved significantly. The study has also established that longer internship programme, in this case 24-week internship as compared to the 12-week internship, has nurtured more intrinsically motivated learners as reflected by the 108 learners surveyed. From the graduate employment survey, graduates have also acknowledged that they had gained useful work experience during their internship. The study has also validated that learners who have completed 24-week internship have exhibited substantially improved intrinsic motivation in 4 IMI subscales, namely Interest, Competence, Usefulness and Effort. Learners who have completed both ITP-12 and ITP-24 have further fed back on important factors that had impacted the success of their internship, namely "Able to learn and apply technical and soft skills," "People they worked with," "Task assigned is achievable" and "Industry Internship Mentor" respectively. All these findings are aligned with the findings from the literature review.

With these findings, the School will be able to work closely with internship companies on key elements thus identified, in providing meaningful and successful internship to our learners. These include the design of the internship tasks, guidance provided by industry mentor and supervisor, and provision of relevant learning activities such that interns can develop professional, personal, and interpersonal skills during their internship.

While the study has validated the effectiveness of structured internship in enhancing workplace learning, there are some limitations in this study. There were several variabilities among the internship placement offered by the hosting companies, including internship tasks and scopes, working environment, guidance and mentorship provided. The different skills in term of mentoring, advising, assessment, communication, etc., would also indirectly impact the internship experience. In addition, company's varying welfare policies for interns could be another confounding variable affecting workplace learning experience.

As part of future work, we can study the relationship between the learners' primary reason in choosing internship, their perception of internship before placement, and how well they perform during the internship. The future study could also investigate the relationship between workplace learning and graduate's employment outcomes. The findings from these studies would further provide clarify on how the Polytechnic would better prepare our graduates for employment and introduce new and meaningful measures to further empower the learners and enhance their workplace learning experience.

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EVIDENCE-BASED REFLECTIVE PRACTICE FOR ENGINEERING REPEAT STUDENTS IN FLIPPED LEARNING

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ABSTRACT

This paper documents the author's application of reflective practice, to enhance quality teaching in a flipped learning context. The implementation of CDIO Standards was demonstrated in the aspects of teaching and learning techniques (Standard 8), faculty development (Standards 9 and 10), as well as assessment and evaluation (Standards 11 and 12). This was particularly evident in the enhancement of faculty teaching competence via evidence-based reflective practice (EBRP). To help an entire class of engineering repeat students to pass their repeat module and avoid expulsion, an EBRP tool was utilized. The tool originated from Singapore Polytechnic's Educational Development department and was subsequently customized by the author into a concise EBRP checklist suited for engineering schools. The 10 core principles of learning embedded in the EBRP checklist enhanced the repeat students' learning experience of their repeat module, via lessons delivered by the author. Coupled with its inherent evidence-based approach, the concise EBRP checklist acts like a structured template for a lecturer to quantify and enhance quality teaching. For data collection and analysis, a "crosshairs" methodology similar to the conventional "triangulation" was employed. The data input was by means of both qualitative and quantitative research paradigms. A "vertical line" was formed by two EBRP data points (qualitative), while a "horizontal line" was formed by two assessment data points (quantitative). Eventually, these lines intersect to form the crosshairs. The two EBRP data points were from both the lecturer and the student, whereas the two assessment data points consist of both formative and summative. Overall, the crosshairs methodology offers a widespread and balanced coverage for data collection and analysis. The tenet of every lecturer's pedagogical technique is to ensure their students achieve the learning outcomes and progress academically. The EBRP checklist used in conjunction with the crosshairs methodology yielded significant positive assessment results. Eventually, majority of the engineering repeat students (above 90%) benefited from the consequential enhanced quality teaching to pass their repeat module, avoiding expulsion and hence progress to their next academic phase of the education system.

KEYWORDS

Evidence-Based, Reflective Practice, EBRP Checklist, Engineering, Repeat Students, Crosshairs, Flipped Learning, Standards: 8, 9, 10, 11, 12

INTRODUCTION

Reflective Practice

Reflective practice has long been applicable in various disciplines, especially in the field of pedagogy. It is commonly regarded as an individual's competency to reflect on his/her actions, in order to be in an iterative process of continuous learning through practice (Schön, 1983). Hence, it is a common habit among lecturers to maintain a teaching journal/portfolio which they update frequently, akin to an engineer's logbook.

One well-known model of reflective practice by Gibbs (1988) used in education is a closed-loop of 6 steps: description, feelings, evaluation, analysis, conclusions and action plan. Another model by Larrivee (2000) highlights the difficulty of good reflective practice, because a lecturer's response to a situation is filtered through 5 screens: past experiences, beliefs, assumptions and expectations, feelings and mood, personal agendas and aspirations. Generally, these popular educational models of reflective practice are inherently subjective as they involve content such as feelings and mood, as shown in Figure 1 below. They may not suit lecturers of science, technology, engineering and mathematics (STEM) schools, who are more accustomed to objective content like formulas and laws.

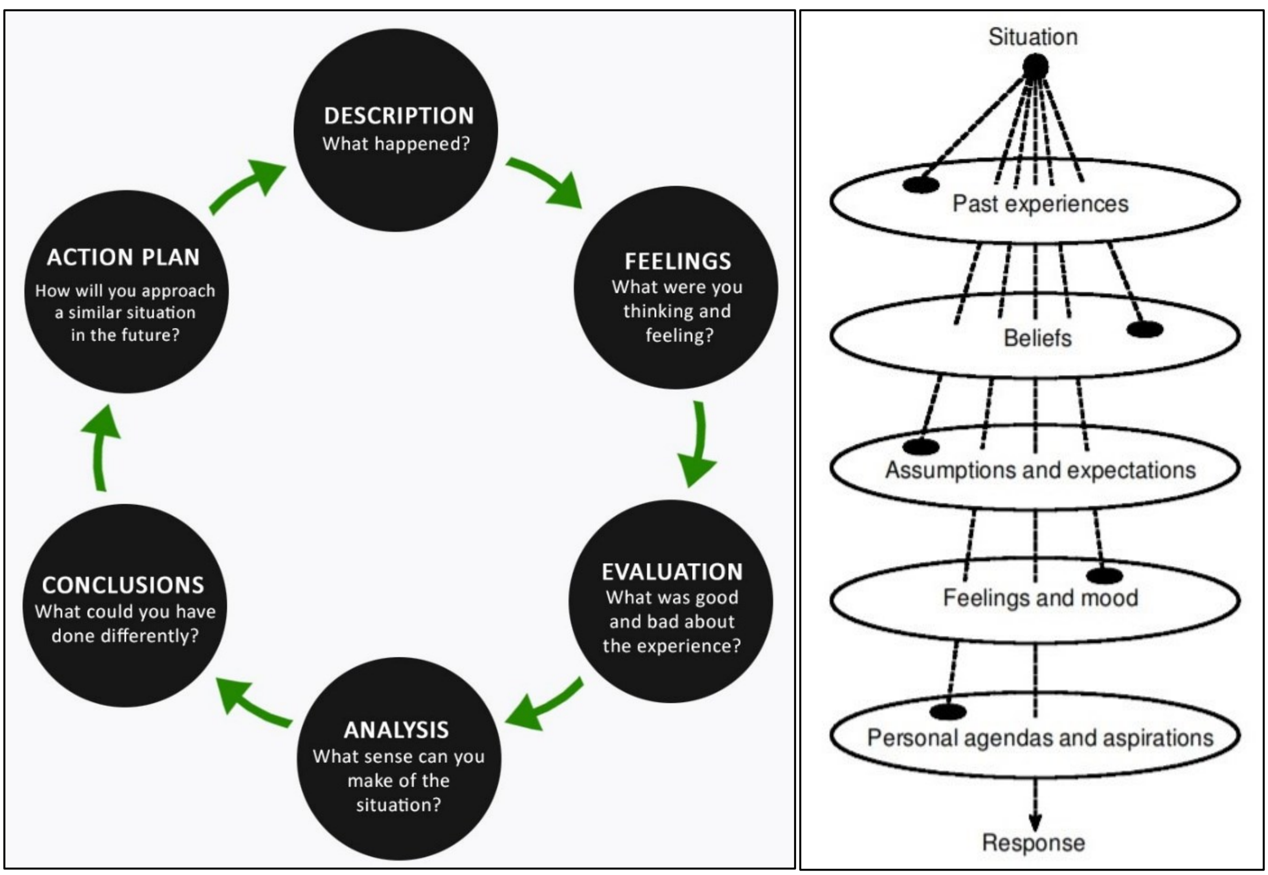

Figure 1. Reflective Practice Models by Gibbs (1988) on left & Larrivee (2000) on right.

Evidence-Based Reflective Practice Tool

One method to somewhat "measure" subjective reflective practice is by the inclusion of objective evidence.

In educational literature, it is highly recommended by researchers for good reflective practice used in education to be evidence-based (Hattie, 2008 & Sale, 2015). This is also applicable to engineering students in a flipped learning context (Sale et al., 2017 & Cheah et al., 2019). For nurses, evidence-based practice to improve patient outcomes via concrete evidence has been applicable since the 1800s by Florence Nightingale (Mackey et al., 2017). For lawyers, the strict compliance of the law of evidence is vital in all legal proceedings (Chen et al., 2018). Similarly for lecturers (such as of engineering schools), the utilization of an evidence-based reflective practice (EBRP) tool should be beneficial for pedagogy (Sale, 2020). To provide lecturers with some prediction of learning effectiveness before lesson and also diagnosis after lesson. EBRP aims to shed some light on how to quantify and enhance quality teaching, which is an ancient theme considered by some lecturers as "mystic arts".

To illuminate quality teaching, 10 core principles of learning (Standard 8) are embedded in the EBRP tool by Sale (2015 & 2020) to quantify quality teaching:

(1) Learning goals, objectives & proficiency expectations are clearly visible to students.
(2) Students' prior knowledge is activated & connected to new learning.
(3) Content is organized around key concepts & principles that are fundamental to understanding the structure of a subject.
(4) Good thinking promotes the building of understanding.
(5) Learning is enhanced through multiple methods & presentation modes that engage the range of senses.
(6) Learning design utilizes the working of memory systems.
(7) Assessment is integrated into the learning design to provide quality feedback.
(8) The development of expertise requires deliberate practice.
(9) A psychological climate is created which is success orientated & fun.
(10) Motivational strategies are incorporated into the design of learning experiences.

These core principles are all mutually inclusive and when used in conjunction with evidence of effectiveness to quantify quality teaching, they enhance quality teaching (Standard 10). Singapore Polytechnic (SP) introduced reflective practice as an annual performance goal for all academic staff in 2018/2019. The inception of this SP policy is to encourage lecturers to conduct reflective practice and even go further as action research (Toh et al., 2020), like this study (Standards 9 & 10). The EBRP tool by Sale (2020) was shared with Academic Mentors (including the author) of all the schools in SP, when he was Senior Education Advisor at the Educational Development department.

BACKGROUND

Flipped Learning Context

Diploma in Mechanical Engineering (DME) is the first such course in Singapore, with a history of 64 years to date and is the flagship diploma with the largest student cohort in SP School of Mechanical & Aeronautical Engineering (MAE). The author is MAE's Academic Mentor as well as the module coordinator of DME core module Thermofluids 1, which is taken by engineering students from 8 different SP courses.

Flipped learning gained immense popularity in the 2010s due to its self-directed approach (Bergmann et al., 2012) and is subsequently recognised as one of SP's educational initiatives (Leong et al., 2019). Thermofluids 1 is a flipped learning module, with online lessons available via SP's learning management system platform Blackboard and also PolyMall. PolyMall is a shared online portal developed jointly by the 5 polytechnics in Singapore, for their students and staff to access online learning content across various disciplines. On a weekly basis, students are instructed to study the e-learning content for preparation, before attending the lecturer's face-to-face lessons. Flipped learning and educational technology also proved to be essential during the coronavirus COVID-19 pandemic. To enforce social distancing, SP unprecedentedly shifted on-campus lessons to online, thus severely disrupting traditional teaching and learning.

Customized Evidence-Based Reflective Practice Checklist

In 2019/2020 semester 1, an entire class of Thermofluids 1 engineering repeat students was assigned to the module coordinator (the author), due to increased failures from the previous 2018/2019 semester 2. This class consisted of 18 Thermofluids 1 repeat students assembled from different MAE courses. If they fail their repeat module, they will be expelled from the school. It is feasible for EBRP to be applicable to engineering students in a flipped learning context, as documented by other SP academic staff (Sale et al., 2017 & Cheah et al., 2019). The author decided to utilize the EBRP tool by Sale (2020) to help his class of engineering repeat students to pass their repeat module and avoid expulsion.

The author customized the tool into a more concise EBRP checklist, such as by minimizing pedagogical jargons and adding numbered checkboxes for the 10 core principles of learning. Due to its inherent evidence-based approach, the concise EBRP checklist also acts like a structured template for a lecturer to quantify and enhance quality teaching (Standards 9 & 10). As a result, the EBRP checklist is suited for engineering schools who are more accustomed to objective content, especially tweaked for MAE.

This customized EBRP checklist was shared with MAE academic staff and lecturers generally found it easy to digest and use for reflective practice. MAE management also requested the author to conduct a formal sharing/training session for all staff in the near future, to help those with poor student feedback scores and those who face difficulties in doing reflective practice for their annual performance goals (Standard 12).

METHODOLOGY

In 2019/2020 semester 1, an entire class of Thermofluids 1 engineering repeat students was assigned to the module coordinator (the author), due to increased failures from the previous 2018/2019 semester 2. The focus group in this study's scope is this class of 18 Thermofluids 1 repeat students, assembled from different MAE courses. If they fail their repeat module, they will be expelled from the school. The author decided to utilize his customized EBRP checklist to help them to pass their repeat module and avoid expulsion. These repeat students were not taught by the author in the previous semester. Therefore, the key intervention process of this study was the author's lessons via his customized EBRP checklist throughout the following semester. This study's objective is to ascertain the effects of EBRP on the repeat students.

Crosshairs Data Collection & Analysis

For data collection and analysis, the author composed and employed an original “crosshairs” methodology, which is similar to the conventional “triangulation” (O'Donoghue et al., 2003). The data input was by means of both qualitative and quantitative research paradigms. A “vertical line” was formed by two EBRP data points (qualitative), while a “horizontal line” was formed by two assessment data points (quantitative). Eventually, these lines intersect to form the crosshairs. The two EBRP data points were from both lecturer and student, whereas the two assessment data points consist of both formative and summative. Overall, the crosshairs methodology “aims” to a widespread and balanced coverage for data collection and analysis. So as to obtain insightful information on the intervention from multiple perspectives. Refer to Figure 2 below for the crosshairs methodology.

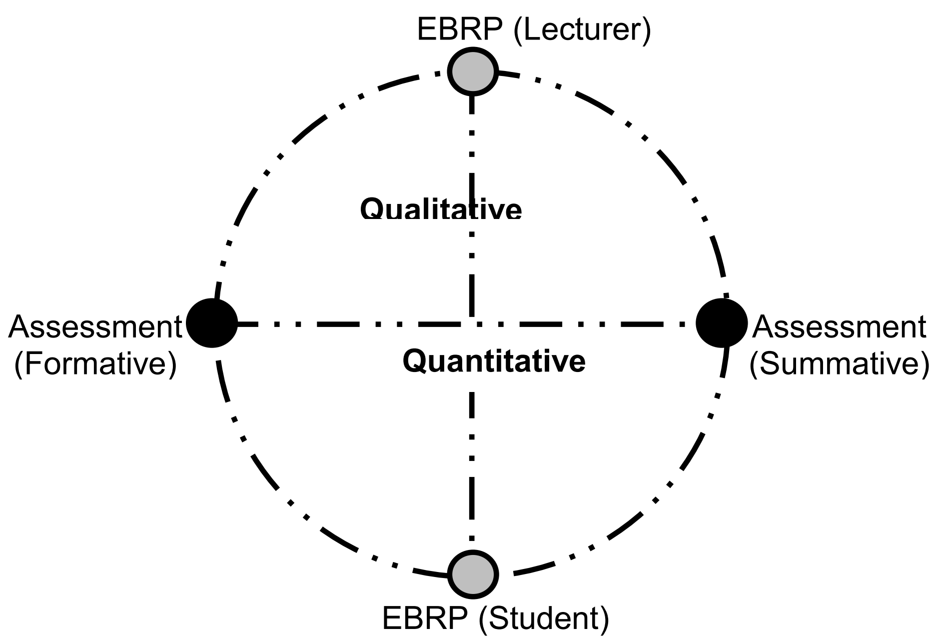

Figure 2. Crosshairs Methodology for Data Collection & Analysis.

For EBRP data points, the lecturer can be the teaching lecturer and/or another observer lecturer, while the student can be the learning student and/or another observer student. For assessment data points (Standard 11), the formative part can be the Mid-Semester Test (MST) and/or In-Course Assessment (ICA), while the summative part can be the Exam or End-Semester Test (EST).

Qualitative Data Collection & Analysis

For the qualitative aspects of this study, EBRP was done by the teaching lecturer (the author) and another MAE observer lecturer from Thermofluids 1 team, in addition to an observer student. The observer student was a former DME student invited to sit-in the lesson and use EBRP for student feedback. Being a recent graduate with perfect Grade Point Average (GPA) of 4, it would be insightful to note this student’s opinions. Considering that this student also attended countless lessons by various lecturers from different schools in SP for the past 3 years.

Quantitative Data Collection & Analysis

For the quantitative aspects of this study, the formative assessment was the MST, while the summative assessment was the Exam. The class of Thermofluids 1 repeat students was not taught by the author in the previous semester. Therefore, the key intervention process was the author's lessons via his customized EBRP checklist throughout the following semester. Their Thermofluids 1 MST and Exam scores were compared for 2018/2019 semester 2 (pre-intervention) and 2019/2020 semester 1 (post-intervention), to obtain insightful information on students' achievement of learning outcomes.

According to the well-known educational research by Hattie (2008), formative evaluation to lecturers has a high effect size of 0.9, considering that the medium is only 0.4. This method is where lecturers take action to get formative feedback on their teaching and then act on it, which is similar to the author's intervention process and this study. There was ongoing evaluation of the author's lessons via his customized EBRP checklist throughout the semester, as EBRP can predict learning effectiveness before every lesson and diagnose after every lesson. This study also commenced during the first term of the semester, such that it is possible to tweak if necessary in the second term based on the MST scores' comparison.

RESULTS & DISCUSSION

Qualitative Data

For the qualitative aspects of this study, EBRP data were from the teaching lecturer (the author) and another MAE observer lecturer (Thermofluids 1 teaching team member), in addition to an observer student (DME recent graduate with perfect GPA). The EBRP checklist was used by the author for his lessons throughout the semester, as prediction of learning effectiveness before every lesson and/or diagnosis after every lesson.

Several noteworthy similar evidence of learning effectiveness were found in the EBRP data by the author, the observer lecturer and the observer student, for one of the author's pivotal lessons in the Thermofluids 1 syllabus:

- ✓ *All core principles of learning were attained.* After all, theses 10 core principles are all mutually inclusive and when used in conjunction with evidence of effectiveness to quantify quality teaching, they enhance quality teaching.
- ✓ *Opening summary of key concepts to enhance memory of both prior & new knowledge.* This corresponds to core principles 1, 2, 3 & 6.
- ✓ *Real-life examples (like Final Year Projects) to reinforce key principles & stimulate good thinking*. This corresponds to core principles 3, 4, 5, 6, 9 & 10.
- ✓ *Interesting variety in delivery methods (like videos) to maintain students' attention.* This corresponds to core principles 5, 9 & 10.
- ✓ *In-class questions-&-answers to ensure clear understanding before proceeding to next topic.* This corresponds to core principles 4 & 7.
- ✓ *Flipped learning online content for practice*. This corresponds to core principles 3 & 8.
- ✓ *Humour & reference to popular trends (like science-fiction movies) to engage students in a fun setting.* This corresponds to core principles 9 & 10.

The 10 core principles of learning by Sale (2015 & 2020) embedded in the EBRP checklist enhanced the repeat students' learning experience of their repeat module, via the author's lessons throughout the semester. On top of the focus group in this study's scope (which is the entire class of 18 repeat students from MAE), another 64 engineering students from SP were also taught by the author and benefited from the consequential enhanced quality teaching of EBRP too.

Quantitative Data

For the quantitative aspects of this study, assessment data were from the formative MST and the summative Exam. The Thermofluids 1 repeat students in the class were taught by other lecturers with no knowledge of EBRP in the previous semester. Therefore, the key intervention process was the author's lessons via his customized EBRP checklist throughout the following semester. Their Thermofluids 1 MST and Exam scores were compared for 2018/2019 semester 2 (pre-intervention) and 2019/2020 semester 1 (post-intervention), to obtain insightful information on students' achievement of learning outcomes. This study commenced during the first term of the semester, such that it is possible to tweak if necessary in the second term based on the MST scores' comparison. Refer to Table 1 below for the Thermofluids 1 MST scores' comparison of the 18 repeat students (anonymous).

Table 1. Thermofluids 1 MST Scores for Pre & Post Interventions.

	Student Name	Pre-Intervention (2018/19 S2) MST Dec2018	Post-Intervention (2019/20 S1) MST May2019
1	A	*ABSENT*	25/50
2	B	13/50	45/50
3	C	3/50	33.5/50
4	D	8/50	11/50
5	E	3.5/50	21.5/50
6	F	25.5/50	30.5/50
7	G	1/50	10.5/50
8	H	7/50	37/50
9	I	2/50	25/50
10	J	27.5/50	40.5/50
11	K	7/50	15.5/50
12	L	15/50	22.5/50
13	M	8/50	*ABSENT*
14	N	5/50	7/50
15	O	5/50	25/50
16	P	8/50	21/50
17	Q	8/50	23.5/50
18	R	14/50	14.5/50

The formative MST scores' comparison showed a significant positive trend after intervention. The average score improved by 30%, from 9/50 to 24/50 marks (rounded off to nearest whole number). Pre-intervention showed only 2 passes, but post-intervention showed 8 passes (including 2 grades of A). Based on the positive outcome of the formative MST, the author decided to continue delivering lessons via his customized EBRP checklist in the second term. This approach is akin to the high effect size method of formative evaluation to lecturers by Hattie (2008). In a hopeful attempt to prepare the 18 repeat students for the summative Exam and to help as many of them as possible to pass at the end of the semester.

Refer to Table 2 below for the Thermofluids 1 Exam scores' comparison of the 18 repeat students (anonymous), as well as their overall final grades after factoring in MST and ICA too

Table 2. Thermofluids 1 Exam Scores for Pre & Post Interventions, & Grades.

	Student Name	Pre-Intervention (2018/19 S2) Exam Feb2019	Post-Intervention (2019/20 S1) Exam Aug2019	Post-Intervention (2019/20 S1) Final Grade Sep2019
1	A	8/100	42/100	**D-**
2	B	17/100	71/100	**B+**
3	C	26/100	41/100	**D+**
4	D	12/100	46/100	**D**
5	E	22/100	40/100	**D**
6	F	16/100	41/100	**D+**
7	G	18/100	52/100	**D**
8	H	25/100	42/100	**D+**
9	I	27/100	47/100	**D+**
10	J	12/100	53/100	**C+**
11	K	15/100	*WITHDRAWN*	
12	L	25/100	35/100	**D**
13	M	7/100	*WITHDRAWN*	
14	N	8/100	29/100	**F**
15	O	10/100	44/100	**D+**
16	P	17/100	47/100	**D+**
17	Q	13/100	*ABSENT*	
18	R	26/100	52/100	**D**

The summative Exam scores' comparison also showed a significant positive trend after intervention. All repeat students who sat for the post-intervention Exam improved in their scores. Their average score improved by 28%, from 17/100 to 45/100 marks (rounded off to nearest whole number). For pre-intervention in the previous semester, all 18 of them failed based on overall final grades and hence repeated Thermofluids 1. Eventually for post-intervention in the following semester, only 1 repeat student in the entire class failed the repeat module and faced expulsion.

Repeat students have always been considered as at-risk students, who require lecturers' monitoring and intervention. The monitoring of engineering repeat students to predict their performance in a flipped learning context was studied by other SP academic staff (Kok-Mak et al., 2019). However, the intervention for such students lack studies that are backed by quantitative assessment data collected and analyzed accurately. Ideally, an accurate study should keep all variables constant, except the variable in the study's objective. National Aeronautics and Space Administration (NASA) compared the data of genetically identical twin astronauts (one was in space, while the other remained on Earth) over a year to accurately study the effects of space on humans (Garrett-Bakelman et al., 2019). Likewise, the author was given the unique opportunity to accurately study the effects of EBRP on the same 18 repeat students learning the same repeat module, via comparing their pre and post interventions' quantitative assessment data over 2 consecutive semesters.

REFLECTIONS & CONCLUSION

The EBRP checklist is a versatile educational instrument that can be utilized both as an intervention and also for data collection and analysis. A lecturer can use the EBRP checklist as prediction of learning effectiveness before lesson and as diagnosis after lesson. To shed light on the ancient theme on how to quantify and enhance quality teaching, hopefully enabling the lecturer to be a "master of the mystic arts". Resembling survey and observation forms, the EBRP checklist can also be used by a lecturer for qualitative data collection and analysis.

Despite the many pros of the EBRP checklist, there exist some cons too. For instance, it is challenging to implement it for a module that has mostly hands-on practical lessons in a workshop (like DME's Computer-Aided Machining). The workshop environment inherently limits the variety in delivery methods and media by the lecturer (core principle 5). All the online lessons delivered during the coronavirus COVID-19 pandemic also faced this same limitation of variety. Moreover, without on-campus physical interaction due to social distancing, it is not easy to engage and bond with the students (core principle 9). Thus, follow-up work in the near future shall involve modifying the EBRP checklist to have alternative versions for practical-heavy and online-heavy modules.

The tenet of every lecturer's pedagogical technique is to ensure their students achieve the learning outcomes and progress academically. The author's customized EBRP checklist used in conjunction with his original crosshairs methodology yielded significant positive assessment results. Eventually, majority of the engineering repeat students (93% based on post-intervention final grades) in the class benefited from the consequential enhanced quality teaching to pass their repeat module, avoiding expulsion and hence progress to their next academic phase of the education system.

The author received a handful of unsolicited appreciation emails from his repeat students, during the wee hours when final results were released for 2019/20 semester 1. The author hereby concludes this paper by sharing one such memorable email below, demonstrating the fruitful implementation of CDIO Standards (particularly Standard 10) via EBRP.

Morning Mr Leong,

I would like to say a really big thank you to you for making second chances feels like it is never the end of the line. Probably i have disappointed you by not being able to turn up some of your lectures and tutorials, but by all means, you are One of the Best Lecturer i have ever met. Making the class lively through your jokes and Marvel related way of learning things, is just something i will always appreciate until the end. Although my results is a D+, but i *believe you have impacted me the most in terms of changing my learning habits. Once again, thank you for believing in us. I hope to see you around in school :)*

Yours Sincerely,
Captain "6F" (anonymous)

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BIOGRAPHICAL INFORMATION

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ASSESSING STUDENTS' PROFESSIONAL CRITICISM SKILLS – A MATHEMATICS COURSE CASE

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ABSTRACT

Becoming a professional engineer (or other professional careers) requires you to give and receive critique in a non-personal and constructive manner. However, many students cannot provide critique to and/or receive critique from fellow students. In this article, an assessment design for a math course where the student can make and review (critique) a mathematical demonstration (proof) is presented. The students find the assessment method fair but different from what they have seen before. To make room for practising the unusual assessment method, the course uses a flipped-class format. Class time is then used to have the students practice this new form. The practise helps the students to figure out what proper mathematical critique is, and they are more prepared for the final exam as well as constructively critique others' work (not only mathematical work but in general engineering work)

KEYWORDS

Assessment, Math, Communication, Standards: 3, 8, 11

INTRODUCTION

Many different competencies are needed for becoming a professional engineer (or other professional careers). In the CDIO syllabus (CDIO Syllabus 2.0), there are close to 500 topical elements arranged hierarchically. It is not explicitly stated under heading 3 (INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION), but addressed by 3.2 Communication that an engineer needs to give and receive critique in a non-personal and constructive manner. However, many students are unable to provide fellow students critique and receive critique from fellow students. In many cases, they take it personally and focus more on "pleasing" the fellow students than giving constructive critique.

Rowntree (1977), in his book "Assessing students: how shall we know them?" notes in the first chapter that "The spirit and style of student assessment defines the de facto curriculum". Ramsden (1992) makes a similar observation: "From our students' point of view, the assessment always defines the actual curriculum" (p. 187) in his influential book "Learning to teach in higher education".

Mathematics is one of the foundations for engineering. Many students see mathematics as a "tool"; something where you find an equation, put in some numbers and get a result. One of my colleagues called the students' way of handling mathematics "equation hunting" – find the equation that needs the kind of values you have and enter them. Furthermore, students often say that you need to learn the proofs you are doing by heart – if you can memorize them, you will pass (with a good grade). However, mathematics is much more than just equations; if you ask a mathematician (s), he will, in many cases, argue that mathematics is a language. Consequently, we need to be able to “speak it”. Learning “to speak” mathematician requires being precise, arguing for the logical transformation of expressions etc.

If being able to professionally critique another piece of work is so important, being able to speak mathematician and what the students’ care about is the assessment, we need to find ways to incorporate professional criticism as part of the evaluation. This article describes one example of such an assessment procedure for the final exam: The student must present a given topic (including at least one mathematical proof) orally, and the two other students provide a professional critique of the presentation, including argumentation of why it was good/not so good (using the language). In this case, the grade is determined by 75% of their presentation and 25% of their ability to professionally critique two of their fellow students. The paper includes a detailed description of the rationale for this type of exam, preparing the students in the class for this new type of exam, the exam's execution, and reflection from teachers and students.

RELATED WORK

A lot of different assessment methods have been proposed. Chappuis and Stiggins (2016) list four main categories: selected response (multiple choice questions and short answer questions), essay (poster presentation, written report), performance assessment (case study, practicum, project, and reflective journal/diary), and personal communication (class presentation, interview, and learning contract). Personal communication (interview) includes the (typical) oral examination, and selected-response (short answer question) includes the (standard) written exam. They argue that each category has advantages and disadvantages in assessing different learning outcomes. For example, a multiple-choice test (selected response) can determine all areas of mastery of knowledge but only some kinds of reasoning and arguing.

Written examinations where students solve mathematical problems seems to be the standard way assessment is done (at least in the United Kingdom and the United States, according to Iannone and Simpson (2012)). In their review of assessment practices, Iannone and Simpson (2011) groups assessment into eight categories: *Closed-book examination (CBE), Dissertation, Open-book examination, Multiple choice test, Oral examination, Regular example sheets, Project* and *Presentation*. They find that *“… it is clear then that the assessment diet is relatively restricted; from just under 50% to just under 100% of the final award comes from results students obtain in CBEs (and recall that our method underestimates the proportion of CBE)*” (p. 190). Videnovic (2017) also argues that “*With the increased emphasis on closed book written examinations, the results in this study show that written exams alone are not sufficient to assess students’ conceptual knowledge and relational understanding, and therefore, there is a critical need for implementing the oral assessments in mathematics courses.*” (p. 1)

Biggs (1996) notes that “*Tertiary teachers almost universally espouse high level aims for the courses they teach […]. However, generalities such as "To think like a mathematician" or "To become a student-centred teacher, sensitive to individual student's needs" do not imply any particular teaching decisions, which leaves other factors, such as student numbers, or* *administrative convenience, to determine teaching and assessment methods. The mass lecture, and formal examinations, thus continue as the default*" (p. 350). Biggs then suggest that a teacher ask three fundamental questions when designing the assessment of the course:

1. What qualities of learning are we looking for; what performances need to be confirmed in the assessment?
2. Should the assessment be decontextualized or situated?
3. Who should set the criteria for learning, provide the evidence, and assess how well the evidence addresses the objectives?

Ernest (2016) claims that "*conversation, consisting of symbolically mediated exchanges between persons, underpins mathematics, and that it does so in four distinct ways.*

1. *Mathematics is primarily a symbolic activity, using written inscription and language and inevitably addressing a reader, so mathematical knowledge representations are conversational.*
2. *A substantial class of mathematical concepts have conversational structures […]*
3. *The ancient origins and various modern systems of proof are conversational, through dialectic or dialogical reasoning, involving the persuasion of others.*
4. *The epistemological and methodological foundations and acceptance of mathematical knowledge, including the nature and mechanisms of mathematical knowledge genesis and warranting are accounted for by social constructivism through the deployment of conversation in an explicitly and constitutively dialectical way. (p. 205)*

Mathematics is about truth. If there is no direct access to mathematical truth, then access to mathematical truth must be indirect via reason or proof. Reasoning and proving are conversational activities. That implies – if it is a "pure" mathematical course and not a course where you apply mathematical results (i.e., solve a differential equation) – you need to have learning outcomes that focus on "talking math", persuading others by logical arguments etc. From that, you need to design an assessment form that assesses the students' ability to convince others and critically evaluate the arguments. In the following, this paper describes such a course and, in detail, its assessment methods.

If we look at the number of articles presented at different CDIO conferences, teaching mathematics is complex. As an example, Gommer et al. (2016) describe a flipped math course supporting mechanical engineering students. They found that "*After the first weeks, participation during lectures and diagnostic tests dropped dramatically. The pass rate of the course was 66%, compared to 80% in previous years.*" (p. 937). Ferreira et al. (2011) described how they used peer instruction to engage the students more in their math course. They found "*Overall results improved with the PI approach, though mostly at the low end of the scale. PI was thus successful in engaging low-end students to fully participate in the course.*" (p. 7). Cabo and Klaassen (2018) describe a project (PRIME) done at TUDelft to modernize their math courses. They found that their "*findings suggest that the approach taken enhances students' learning performance in maths education. The main results show that students have a more active learning experience compared to the traditional setup of these courses, leading to more engagement, more interaction and better results*." (p. 704)

THE CONTEXT

The case in this article is a discrete math course. The course (ITDMAT) is a 5 ECTS point (60 ECTS = one year of full-time study) course offered to students from five different study programmes: students in the final year of their professional bachelor study in software technology (ICT), electronics (E), power electronics or health technology. Before this course, these students have had two years of mandatory classes and half a year of internship (and some of the students half a year of elective courses). The last study program where students from computer engineering have the class as a mandatory course in their second semester. The students are from at Aarhus University Department of Electronics and Computer Technology. The course is taught in a semester structure (a semester = 14 weeks of teaching and four weeks of examination). This class had 33 students; the course language is English and had two teachers (the author and one more). A more detailed description of a previous course holding can be found in Bennedsen and Lauridsen (2014).

Learning Outcome

The learning outcome of the course was the following:

When the course is completed, the student is expected to be able to:

- define and analyze the fundamental concepts of propositional logic and predicate logic,
- explain and apply modelling using discrete mathematics such as sets, lists, functions, relations and graphs,
- describe and apply various proof techniques such as induction, contradiction, contraposition, direct.

Learning Material

The course is designed as a flipped classroom course (Bishop & Verleger, 2013). Consequently, the students should acquire the knowledge they typically get from the lectures before the class takes place and use the class time to discuss and get more personalized help. Typically, this is done by some video-mediated material. I have chosen prefabricated videos from different sources in this course and other forms, all freely available on YouTube. None of the videos is produced exclusively for this course but selected by the teachers. Apart from the videos, the assigned textbook (Cusack and Santos, 2019) looks pretty suitable for the purpose since it includes many different exercises that students can work with outside the class hours.

Course Arrangement

The course contains nine topics, each lasting approximately two weeks. The following section describes the assessment method in detail, including seven mandatory written assignments and a final oral exam. There are four class hours per week (two hours Monday and two hours Thursday), so the general structure of the course is like follows:

Monday week X	
1	Highlights of this weeks' topic (this is the lecture)
2	individual work with the mandatory assignment
Thursday week X	
1	workshops[6]
2	workshops (in some weeks trial exam)
Monday week X+1	
1	Feedback on assignment from last round
2	individual work with the mandatory assignment
Thursday week X+1	
1	Workshops
2	Preparation and discussion about the exam question related to this week's topic Exam presentation and review

THE ASSESSMENT METHOD

Constructive alignment focuses on ensuring deep learning. The quotes from Ramsden (1992) and Rowntree (1977), in the introduction, suggests that we "just" shall assess a way where the students are "forced" to use deeper learning. As Struyven et al. (2005) note, there is no direct correlation between the assessment method and the students' learning approach. They note *"it is obviously easy to induce a surface approach, however, when attempting to induce a deep approach the difficulties seem quite profound*" (p.328). Consequently, one cannot look at the final exam in isolation but need to take a holistic view of the learning.

Mathematics is about conversation; a conversation about *Truth (*Ernest, 2016). Since the conversation (i.e., trying to persuade others that it is true, or – as it is typically called in mathematics – prove it) have special "rules", the students must learn the conversation format. Proofs are different from arguments, as they are comprehended in argumentation theory. Perelman and Olbrechts-Tyteca (1971) separate arguments from demonstrations, such as mathematical proofs. Demonstrations are impersonal; arguments are not. Arguments are, in their entirety, relative to the audience to be influenced. Ernest (2016) describes the following four requirements "*to establish the truth of mathematical knowledge by these means the following conditions are a minimum requirement. We must have:*

1. *A starting set of true axioms or postulates as the foundation for reasoning;*
2. *An agreed set of procedures and rules of proof that preserve truth, with which to derive truths from the axioms;*
3. *A guarantee that the procedures and rules of proof are adequate to establish all the truths of mathematics or at least of the theory in question (completeness); and*
4. *A guarantee that the procedures and rules of proof are safe in warranting only truths of mathematics (consistency)."* (p. 194)

That conversation can be oral or written, so we need to address both kinds of conversation. The assessment method contains both a written and an oral part consequently.

[6] A workshop is a problem/exercise that students solve in small groups for 15 min and the 5 minutes of presentation of the work by a selected group.

The Written Assessment

Traditional math exercises are written. As described earlier, the students need to persuade (or demonstrate to use the term from Perelman and Olbrechts-Tyteca (1971) by writing a proof that starts with what has already accepted knowledge, using procedures that preserves the truth, derive at the desired conclusion. Thus, the students need to create a proof and evaluate the proof – is it following the rules, i.e., following the procedures that preserve the truth.

Reading – and memorizing – proofs is at the heart of many mathematics courses. In our case, the students first read proofs (in the material presented before the class) where the procedure steps are described (why is this step preserving the truth). In the material, they also make part of a proof (fill in the details in a proof, see Figure 1) and evaluate proofs (see Figure 2).

⋆**Fill in the details 2.4.** Use the definitions of even and odd to prove that the sum of two odd integers is even.

Proof: If x and y are odd, then $x = 2c + 1$ and $y =$ _________ for some integers c and d. Then $x + y = 2c + 1 + 2d + 1 = 2(c + d + 1)$. Now _________ is an integer, so $2(c + d + 1)$ is an _________ integer. □

Figure 1. Fill in the details (Cusack & Santos, 2019, p. 8)

⋆**Evaluate 2.8.** Evaluate the following proof that supposedly uses the definition of odd to prove that the product of two odd integers is odd.

Proof: By definition of odd numbers, let a be an odd integer 2n+1 let b be an odd integer 2q+1. Then (2n+1)(2q+1) = 4nq+2n+1 = 2(2nq+1)+1. Since 2nq+1 is an integer, 2(2nq+1)+1 is an odd integer by definition of odd. □

Evaluation ____

____

____

Figure 2. Evaluation of a "proof" (Cusack & Santos, 2019, p. 10)

In the class hours, the students create proofs on their own (or actually in pairs) called workshops in the course arrangement section.

Seven mandatory assignments do the written part of the assessment of the students. It is not part of their final grade (this is very difficult to do in Denmark due to the regulations on student assessment set by the ministry). Still, to be allowed to sign-up for the final exam, all seven assignments need to be accepted by the teachers. The assignment contains proofs that the students have to make (closely related to the proof they made at the class workshops). The Assessments also follows a *write and constructively critique* pattern. Firstly, the students hand in their solution (i.e., their proofs). They can do that individually or in pairs. After they have handed it in, they have to give feedback to two or three other students' solutions. After that, the teacher evaluates both the solution and the feedback that the students have provided and gives them feedback on both.

Oral Assessment

The final exam of the course is oral. Here the students are assessed in groups of three (if the total number of students is not dividable by three, one or two extra students are included, and one or two will be on the bench in each round). During the exam, each student has three roles:

- **Presenter**: The student presents one of the topics. The presentation must include at least one proof and relevant axioms etc. This part takes 12 minutes
- **First reviewer**: The student gives feedback on the presenter. The feedback must focus on the presents ability to make a mathematical demonstration, i.e., their ability to make a valid and sound mathematical presentation
- **Second reviewer:** The students follow up on the first reviewer by commenting on the review and other things that the first reviewer did not address in her/his review

After the first round, the presenter becomes the first reviewer, the first reviewer, the second and the second reviewer becomes the presenter. Then one more round where the students rotate roles. The final grade is determined by 75% of the student's presentation and 25% of the student's review.

The reviewer acts like an opponent. Commonly, opponents are related to argumentation, but in this case, the more have the role as a reviewer of a demonstration of a piece of scientific work. The students have not tried this form of oral assessment before; consequently, we practice during class hours. At the end of two weeks, the students prepare (in groups) a presentation of the topic and do a trial exam. In the beginning, it is my experience that the students are reluctant to critique a fellow student and focus on the presentation technique. Doing this in class has several advantages: 1) The students wrap up the topic by going back and figure out what they would like to include in the presentation (i.e., the most important thing) 2) The students get to know the format and thus are much more relaxed when the final examination comes.

During the COVID-19 pandemic, all teaching has been moved online. This gave rise to the practical problem of "how can a student present proofs online?" Most online teaching tools like Zoom or Teams have a shared whiteboard, but writing on it using a mouse is a problem. Some students have a tablet with a stylus (iPad, touch PC etc.), but that is a minority. Moreover, we do think we can require the students to buy one. Our solution has been using a mobile phone filming a piece of paper – see Figure 3. If the presentation is done synchronously, the mobile phone is just another participant; if done asynchronously, the students record a video.

Using a mobile phone to record the students' presentation made it possible to do that before class. Then – in class – we can put the students in smaller groups (3-4 students per group) and review each other's presentation. The students need more guidance in doing a good review (they typically focus on the presentation technique things rather than the subject things), but in general, this has improved the amount of feedback. Practically, we have gathered the students at the end, where we will watch a presentation together, and the teacher then gives the critique.

Figure 3. Mobile phone recording a presentation

THE STUDENTS VOICE

In one of the offerings of this course, we interviewed ten students. The interview focused on the course design, including the creation of the assessment. The interviews were done after the examination. In general, the students found the assessment format fair and supporting the course's goals; there was alignment between the learning outcome and the assessment method. As one of the students said in the interview:

> *"I would say there was a really good connection between the way we were taught and the way the exam was done; it was really well connected."*

A typical problem in Denmark is the so-called "Law of Jante[7]." This implies that you do not want to talk negatively about others etc. Using class time to practice made the students understand that the review did not influence the presenter's grade but the reviewer's grade. As one student explains

> *"It was a really good exam ... It was a bit difficult to find out how much was needed in the individual exam question ... For me, that Law of Jante disappeared a bit when we went in behind that door there ... we knew that ... that we can not make it worse for each other "*

CONCLUSION

In the article, I have presented an assessment design for a math course where the student can make and review (critique) a mathematical demonstration (proof). The students find the assessment method fair but different from what they have seen before. We use a lot of class time to give our rationale for the assessment method and practice this new form. The practise

[7] It characterises not conforming, doing things out of the ordinary, or being personally ambitious as unworthy and inappropriate. See https://en.wikipedia.org/wiki/Law_of_Jante

helps the students figure out what proper mathematical critique is, and they are more prepared for the final exam and constructively critique others' work (not only mathematical work but in general engineering work).

Moving the presentation to a digital form has increased the feedback when the students are present in class (either physically or synchronously online). We will continue doing this – also when we are allowed to come back to the university after the COVID-19 pandemic.

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BIOGRAPHICAL INFORMATION

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DEVELOPING AND ASSESSING TEAMWORK WITH ENHANCED TEAM-BASED LEARNING APPROACH

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ABSTRACT

Singapore Polytechnic (SP), Civil Engineering course reformed its curriculum according to the CDIO principles since 2004. Teamwork is an essential interpersonal skill in the CDIO syllabus to be integrated as an important learning outcome into the engineering curriculum. This important interpersonal skill is usually developed and assessed through project-based learning (PBL) approach. The author combined the approach of PBL and Team-based Learning (TBL) which is an active learning instructional strategy that engage learners as an individual or a group in thinking and problem-solving activities. TBL is an approach substantiated with four essential elements recommended by Michaelsen (2008) to ensure a successful implementation with highly reliable learning outcomes. It is an approach making opportunities in a blended learning environment with group work central to both exposure and enhancement of learner's ability to apply the course content to their project work. This paper describes the infusion of team-based learning essential elements into the classroom and a mini-project in a blended learning environment to develop and assess teamwork skills. Learning activities are designed for students to apply their course content knowledge that they have learnt in the course. The paper then presents summaries of results for both quantitative and qualitative students' feedback as well as identifies the implications for enhancing practice in teamwork development and assessment.

KEYWORDS

Team-based learning, project-based learning, blended learning, teamwork, assessment, journaling, peer assessment, standard: 2, 3, 8, 11.

INTRODUCTION

Skills to work in a team and as a team have become an important part of the working culture and many companies now look at these skills when evaluating a person for employment. Hence, it is important that students learn to work in a team environment so that they will have these skills when they enter the work force. Hence, it is important that students learn to work in a team environment so that they will have these skills when they enter the work force. From a literature review on teamwork skills (Richard Y. Chang(1994), Stephen C. Armstrong(2008), Maginn, Michael D.(2004)), it is gathered that in general, teamwork skills require to form an effective team include communication and active listening, resolving conflict, team diversity and team motivation. These skills are usually termed as teamwork in any group work project. Jessie Ee et al. (2004, p.49) advocated the importance of a new approach in curriculum where the focus of instruction is shifted to encouraging strategic and motivated students, rather than delivering specific domain content. Developing teamwork skills has to go beyond the traditional instruction and into a new approach such as team-based learning (TBL) for students to learn and practice and for lecturers to facilitate teamwork skills. The primary learning objective in TBL, resonated with Jessie Ee et al. (2004) point on new approach in curriculum, is to go beyond covering content and focus on ensuring students have the opportunity to practice using course concepts to solve problems in small group learning with emphasis on both individual and group accountability (Michaelsen et al., 2009).

However, monitoring and assessing teamwork is often not clear and sometime neglected. Assessment of teamwork is a tedious and difficult task and would be inaccurate and unfair if monitoring of teamwork can only be done during the classroom contact time. Monitoring is usually not possible outside the classroom. With the provision of technology, in particular, tools in Blackboard (BB) to trace the evidence of the team's communication and progressive work done outside the classroom contact time as well as Learning Activity Management System (LAMS) to administer self & peer assessment. This provision is important to create a blended learning environment which combines face-to-face instruction to achieve an independent and collaborative learning as well as a fair system of assessing teamwork.

A MINI PROJECT FOR STEEL STRUCTURE ANALYSIS, DESIGN & DETAILING OF A SINGLE STOREY BUILDING

Structural Steel Design & CAD is a core module offered in semester 2 of year 3 in the Diploma in Civil Engineering with Business (DCEB) which has been the final year capstone project integrated into the DCEB curriculum since it first adopted the CDIO approach.

The tasks of the mini project for students consist of load calculation, design of steel structural members to EuroCode, and 3D modelling and detailing of a real-world single storey frame building with minor modifications to better suit for students' learning of the module.

The module had been delivered in a traditional way supported partially by project-based learning approach until AY18/19. Team Based Learning (TBL) method has been introduced to this module in order to improve the students' performance in a holistic way, and hence the delivering of this module to students has been changed significantly ever since.

The min project was also re-developed in order to fit the key principles and practices of TBL.

TEAMWORK DEVELOPMENT

Team Based Learning

According to Michaelsen & Sweet (2008), the success of TBL lies in the following 4 essential elements of TBL successfully implemented:

- **Groups** - groups must be properly formed and managed,
- **Accountability** - students must be accountable for the quality of their individual and group work,
- **Feedback** - students must receive frequent and timely feedback, and
- **Assignment Design** - group assignments must promote both learning and team development.

Figure 1 represents our adapted TBL instructional activity with a mini-project (project-based learning) to enhance the assignment design element with real world context.

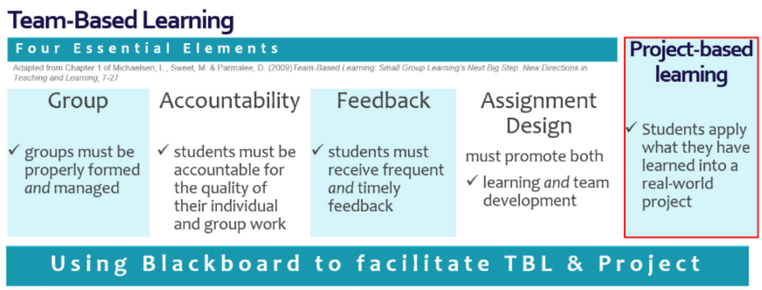


Figure 1. TBL Essential Elements adapted from Michaelson (2009)

TBL is designed to provide students with both conceptual and procedural knowledge (Michaelsen, 2009). Our approach to develop teamwork skills is to adopt blended learning which requires students to learn both in face-to-face (F2F) and out of the classroom with team-based learning as the primary enabling element and requires student to self-regulate in a guided environment with the help of technology. Self-regulated learners apply flexible approaches to problem-solving that are adaptive, persistent, self-controlled, strategic, and goal-oriented. Scott G Paris (2004, p58) recommended the following three ways to develop self-regulated learner which resonates with our self-directed learning (SDL) holistic implementation blueprint underpinned by SP SDL Model (2018) and Gibbons' model (2002).

- setting appropriate goals that are attainable yet challenging;
- managing time and resources through effective planning and monitoring;
- reviewing one's own learning, revising the approach, or even starting anew.

Majority of the class time is used for team assignments and focus on using course content to solve problems in a real-world project. Primary role of lecturer has shifted from delivering content to designing and managing the overall instructional process. Student's role shifts from being passive recipients of information to one of accepting responsibility for the initial exposure to the course content so that they will be prepared for the in-class teamwork and later for the mini-project. Susan A. Ambrose et al. (2010) indicated in her book on "How Learning Works" that research suggests when students are provided with a structure for organizing new information, they would learn more and better. The methodology adopted here is to pace the project specification requirement to align with the course content and to have a permanent or same group of teams working on their individual and group learning in the classroom and in their mini-project work. Figure 2 outlines how time in a one lesson (3 hrs) of TBL is organized in the context of Structural Steel Design & CAD final year module.

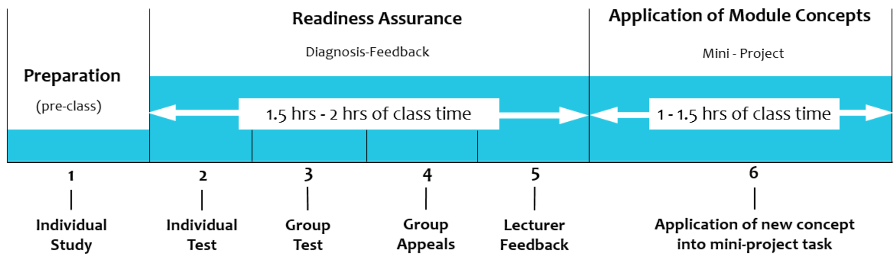


Figure 2. A Contextualised TBL Lesson

Students are strategically organised into permanent groups for the entire semester. Module content are designed and organised in topic to be in sync with the mini-project tasks as illustrated in a final year module - Structural Steel Design & CAD which is described in the later section. Before every lesson, students must study the scheduled topic because each lesson begins with the Readiness Assurance Test (RAT). This RAT consists of a short multiple-choice quiz (MCQ) or short questions depend on the topic. This is to test the key ideas of the topic which require students to first complete as individuals, and then they take the exact same test again as a team, coming to consensus on team answers. At the end of RAT, students receive immediate feedback on the team test and follow up with a time for lecturer to clarify any misconceptions arising from the test results. This can be done efficiently with the use of technology (BB - Item Analysis) * which allow lecturers to quickly see which questions might need revision and clarification with students. After the RAT is completed, the remaining time is spent on mini-project that require them to practice applying the module content. To encourage students to remain reflective throughout the project, they are required to write journal and record it as a blog in the Black Board e-learning portal. The blogs are only visible or private to the individual student or team and the facilitator.

*[*Item Analysis is a tool in BB that measure the effectiveness of MCQ.]*

Establish the Team

As the saying goes, a good beginning is of great importance to the success of any task. TBL requires the lecturer to form a diverse group with different learning ability as well as demographic characteristic such as gender and ethnicity to form an effective team. In this pilot run, diverse groupings are formed by the lecturer from the start with different learning ability by taking their overall grading in the course and two individual modules that contributes important prior knowledge as well as characteristic such as gender, class group and ethnicity.

Susan A. Ambrose et al. (2010) indicated in her book on “How Learning Works” that research has suggested when students are provided with a structure for organizing new information, they learn more and better. Although students have learned teamwork skill in another module, they would learn more and better during their application in the mini project if there is a structured methodology for them to follow. From a literature review in search for a structure, the steps to establish the team were adapted from Stephen C. Armstrong (2008). These steps are infused into the mini project as tasks that cover four activities that the team must complete in the classroom to make sure each group can function as effectively as possible both as a learning team and as a project team. The four activities are listed below:

Activity 1: Confirm Team Membership
The purpose of this activity is to form a diverse team with a mix of learning abilities based on their GPA and demographic characteristics like gender and ethnicity (this is done by the lecturer before the term starts). This is also to get the team to assign role according to their strengths. They are also encouraged to rotate their roles to experience different role in a team.

Activity 2: Common Understanding
The purpose of this activity is to make sure everyone in the team has a common understanding of what the TBL is and what this project is about, why they are here, and what the team will work on.

Activity 3: Agree on Team Rules and Operating Values
The purpose of this activity is to avoid some common predictable conflicts. Rules and operating values such as meeting start times, duration, locations, rules for late or missed meetings, etc. that the team must agree to.

Activity 4: Agree on Plan and Schedule
The purpose of this activity is to force the team to think through the steps required in activity 1 and develop an agreed plan and schedule against which to measure progress with the required deliverables and deadline constraints.

Students are expected to document their work done in these activities and post to BB-Group so that the team can refer to them anytime and anywhere. With the use of technology, monitoring of teamwork has become possible with evidence of work done, minutes of meeting and discussion notes that the team has posted to BB-Group.

Teamwork Assessment

The new approach in curriculum which has the focus of instruction shifted to encourage strategic and motivated students, rather than delivering curricula or managing classroom behaviour (Jessie Ee, et al., 2004) will result in a change in teamwork assessment. Both assessment and instruction need to be synchronized. Dochy (2001) referred to assessment as not only measuring knowledge gained but also student involvement, their application of that knowledge, integration in learning environment and knowledge construction in real life situations.

The assessment on the mini-project is based on the group work done in and out of the class each week and the journal blog in the e-learning portal in BB. Rubrics are used in assessing the students' performance in the mini project. While rubric may address the assessment on technical content and attributes by the lecturer with evidence of work done in the e-learning portal, a more complete assessment is necessary on teamwork outside the classroom.

Self & Peer Assessment

Teamwork and its dialogue session outside the classroom can be further assessed by self & peer assessment. Peer assessment involves using peers' comments in assessing the quality of assignments [Roberts, 2006]. Generally, there are two forms of techniques of self and peer assessment in teamwork. Technique 1 is for teamwork weightage that does not contribute much to the project/activity final marks. Technique 2 is where teamwork is very much emphasized and contributes a high weightage to the project final marks. Technique 2 is adopted here for the self and peer evaluation. Five categories of assessing teamwork effectiveness were taken from www.CATME.org (a free website) for the self & peer evaluation. The five categories are:

1. contributing to the team's work;
2. Interacting with teammates;
3. Keeping the team on track;
4. Expecting quality;
5. Having relevant KSAs (knowledge, skills and abilities).

We believed that these 5 teamwork competencies are the essentials to build teamwork skills that include communication and active listening, resolving conflict, team diversity and team motivation.

Self and peer assessment were usually done at end of the project. This acts as a summative assessment instead of a formative assessment for learning. In order to do a formative assessment for learning, self-assessment is conducted at the mid of the semester for learners to do self-reflection on their contributions, giving them time to catch up with their contribution and to do improvement as well as for lecturers to adjust instructional strategy when necessary. At the end of semester, learners will then do the peer assessment.

Self & peer assessment is administered through two different tools because of administration challenges and benefit in each tool. Self-assessment is administered through BB at mid semester and self & peer-assessment is administered through LAMS at end of semester. BB has the flexibility to deploy self-assessment independent of peer assessment. LAMS though has no such flexibility, but it has a good mechanism to calculate an adjustment factor (SPA factor) to convert group marks into an individual mark for a project. A SPA factor of > 1 indicates a student's contribution was rated above the average contribution of the team. A SPA factor of < 1 indicates student's contribution rated below the average contribution of the team.

STUDENT FEEDBACK AND DISCUSSION

A survey was conducted at the end of the learning experience to gauge the effectiveness and relevancy of TBL and self & peer assessment. Feedback survey of students at three instances were carried out:

a) From 2 groups of students who have experienced the new approach of teaching (TBL) in an elective module and the formative self & peer assessment administered through BB with no SPA factor considered (25+26 students and 50 responded) in AY19-20 term 1 and 2 respectively.

b) from 2 groups of students who have experienced the new approach of teaching (TBL) in the core module as described in this paper and the formative self & peer assessment administered through BB with no SPA factor considered (17+17 students and 28 responded) in AY19-20 semester 2.

c) from another 1 group of students who have experienced the new approach of teaching (TBL) fully online in an elective module and the formative self-assessment administered through BB and summative self & peer assessment administered through LAMS (24 students and 21 responded) at end of AY20-21 term 1.

They were asked to respond to questionnaires with rating of 1(not true) to 5(very true). Quantitative and qualitative responses were collated and tabulated in Table 3a – Learning Experience, Table 1b – Self & Peer Assessment and Table 1c – Using Technology to manage and monitor Learning and Project.

Table 1. Percentage of Responses > rating 4

a) Learning Experience

Question	Case				
	AY19-20 Sem 1 Elective (a)		AY19-20 Sem 2 Core (b)	Average of (a) and (b)	AY20-21 Elective
	(25 students)	(25 students)	(25 students)		(c) (21 students)
	Term 1	Term 2	Term 1 & 2		Term 1
Formative Self & Peer Assessment	**BB**	**BB**	**BB**		**BB & LAMS**
a) It gives me a chance to reflect on my contributions early so that I can make improvements.	68%	88%	72%	76%	81%
b) It gives me more time to assess my team members based on their contribution they have input.	68%	88%	72%	76%	**62%**
c) It is a more fair and meaningful peer assessment	44%	88%	52%	62%	72%

b) Formative Self & Peer Assessment

Question	Case			
	AY19-20 Sem 1 Elective		AY19-20 Sem 2 Core	AY20-21 Elective
	(a) (25 students)	(a) (25 students)	(b) (25 students)	(c) (21 students)
Learning Experience:	Term 1	Term 2	Term 1 & 2	Term 1
a) It has given me more time or opportunities to learn and work as a group	60%	84%	76%	77%
b) It has helped me to be more aware of my learning progress (e.g using BB - my Grade and feedback to your readiness test either in the classroom or via BB)	60%	88%	76%	81%
c) It has helped me to improves my learning, either because of the help from my group or because I am able to help	56%	84%	76%	67%
d) It has helped me by giving me opportunities to connect the knowledge I have learnt and applied it in my project	60%	84%	**92%**	77%
e) It has actively engaged me into focus learning weekly leading me to be a self-directed learner (SDL)(Note: a SDL plans, monitor & manage their own learning and extended their learning into other areas)	60%	76%	72%	67%

c) Percentage of Responses > rating 4 (Using Technology)

Question	Case	
	AY19-20 Sem 2 Core	AY20-21 Elective
	(b) (25 students)	(c) (21 students)
Using Technology to manage and monitoring learning and project	Term 1 & 2	Term 1
	BB	BB
a) It provides a platform to record reflection, discussion and work done by the team	76%	72%
b) It provides a platform to manage and monitor team progress	80%	**57%**
c) It provides a platform of work evidence done by each member and as a result teamwork assessment is fair.	68%	67%
d) It provides a platform and opportunity for us to feedback on each other work in the team.	**56%**	72%

Learning experience

Students' reflections on their learning experience in the new teaching approach were positive and encouraging. These reflections, together with the above percentage rating have indicated that students recognized the benefits of the enhanced TBL with the project-based learning integrated and to learn as both a learning and project team.

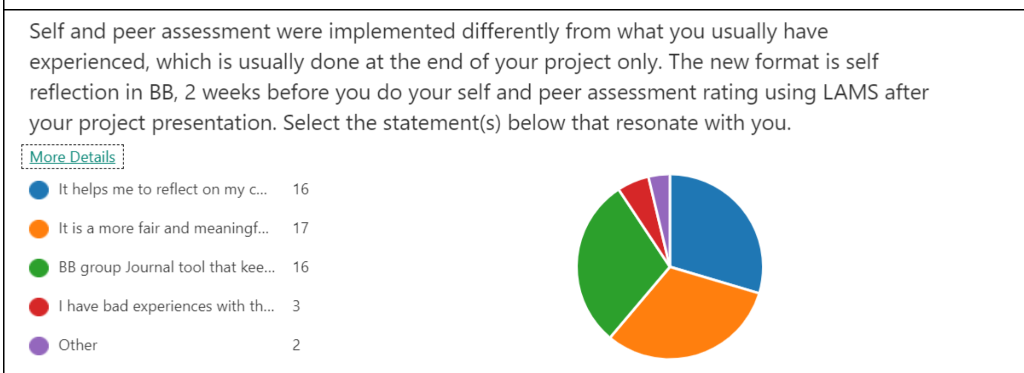
The improved percentage rating in the 2nd attempt in AY19-20 has indicated that lecturers' familiarity with the new teaching approach is a key consideration to improve students' learning experience. When the same teaching approach is ported to a different context module in AY 19-20, result has indicated an improved percentage rating at the opportunity to connect knowledge into project work (92%). Although the percentage rating for the 1st attempt in AY19-20 term 1, had been on the lower side but their reflections on 1 thing they like most in this learning experience were encouraging. Things that they don't like were mostly either problem on the submission logistic or workload and some due to personal motivation challenges.

Formative Self & Peer Assessment

The percentage rating using BB as the administering tool were averaged (Table 1b) and compared to the case using BB & LAMS. The higher percentage rating in the AY20-21 term 1 has shown an improvement on the process by using both BB and LAMS to administer self & peer assessment. These results together with students' reflections as well as feedback from a mid-semester home based learning (HBL) survey tabulated in Table 2, indicated that students have benefited from this formative assessment. However, a lower percentage rating of 62% (Table 1b) has highlighted a possible need to further improve the process of peer assessment.

Table 2. Mid-semester HBL Survey on Self & Peer Assessment

AY 20-21 - Formative Self & Peer Assessment



- It helps me to reflect on my contributions early so that I can make improvements.
- It is a more fair and meaningful self & peer assessment
- BB group Journal tool that keep record of our contributions to the group has made our individual work done more evidence
- I have bad experiences with the new format of self and peer assessment

Using Information and Communication Technology (ICT) to Manage and Monitoring Learning and Project Work

Assessment for learning in teamwork is now possible with more accuracy and efficiency with technology that allow lecturers to gain insight on their students' learning progress as a group and at the same time to allow students to do collaborative learning. However, the percentage rating in Table 2 have indicated that most students do not see the benefit of using technology to manage and monitor their learning and project progress.

Conversely, there were some qualitative students' reflections have shown otherwise. We believe if given repeated opportunities to students to practice using ICT to manage and monitor their learning and project over a period of time from year 1 to year 3 of their study in the course, they will then see the benefit and develop a habit of mind. As quoted by Aristotle, "We are what we repeatedly do. **Excellence**, then, is not an act, but a **habit**."

CONCLUSION

Teamwork skill is an essential part of any successful collaboration projects both in the context in the industry and in a school setting. Thus, it must be a part of the school training experience. With the advancement of technology that facilitate participatory information sharing and collaboration on the World Wide Web, TBL has assisted and improved the way lecturers develop, assess and monitor teamwork, as well as change the way students learn.

This new approach involves instructional shift from a traditional classroom to a blended learning classroom that needs learners to do pre-class reading and form learning team as well as changes in the assessment of teamwork. The pre-class learning is similar to the flipped learning which is also another blended learning format in which online work on key underpinning knowledge completed before more application-orientated work is facilitated in the face-to-face context (Bergmann & Sam's, 2012). TBL essential elements, especially the readiness test component can be seen as one of the approaches for facilitation to enhance students learning in the face-to-face context.

As we are switching to online instructions in an attempt to slow the rapidly evolving COVID-19 pandemic, many are scrambling to convert F2F classes to online classes – a process that take some thoughts and often takes weeks or months of preparation and now has to be done in a matter of days. Not only has this sudden turn-around forced us to scramble but changing delivery methods has left many of us wondering how we are going to provide a seamless learning experience to our students. Those who are already using the Information and Communication Technology (ICT) to manage and monitor learning and especially project work have benefited as they continued seamlessly to facilitate learning and project work using the ICT. An ICT initiative to manage and monitor project work that the main author has been trying to instil into both teaching staff and students for many years is now made possible for 100% adoption by a pandemic without much resistance. They now see the necessity and urgency to use ICT.

In conclusion, this paper represents the work of a few iteration of an action research in finding new approaches to develop teamwork and its assessment. Future investigations will further improve and validate the development of teamwork skills and its assessment in addition to TBL as well as self and peer assessment in assessing teamwork.

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BIOGRAPHICAL INFORMATION

Soo-Ng Geok Ling passion for teaching and technology can be traced back to my early-professional days with her first job in supporting the transforming construction industry to use IT solutions in engineering projects. The reason? She likes getting people excited about how technology can help them to be efficient. She is now a senior lecturer in the School of Architecture and the Built Environment at the Singapore Polytechnic. She is committed to education through improving students' learning and mentor teaching staff through effective professional development.

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CDIO APPROACH FOR DEVELOPMENT OF TEMPERATURE RISE MONITORING SYSTEM

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ABSTRACT

A Research and Development (R&D) project sponsored by both the Building Construction Authority (BCA), Singapore and Admaterials Technologies Pte Ltd for the development of an Adiabatic Temperature Rise (ATR) testing system to replace on-site mock-up tests for preventing cracks of concrete, improving concrete durability and sustainability, and enhancing construction productivity was successfully completed last year. Conceiving, Designing, Implementing, and Operating (CDIO) approach was used for the development of the system by a team consisting of two academic staffs, two groups of Final Year Project (FYP) students and an industry collaborator. This system has won the Singapore Polytechnic R&D Award 2018 and Singapore Ministry of Education Innergy Award 2018. This paper describes in detail how the team used CDIO standards especially standards 5, 6, 7 and 8 as a guideline to conceive, design, implement, and operate the system. It also illustrates in detail how the final year project (FYP) students used Singapore Polytechnic's Advanced Materials Technology Research Centre as a learning workspace for achieving pre-defined learning outcomes. In future a capstone project, which requests students to conceive and design a "recipe" and test concrete samples cast using the "recipe" by the ATR system for checking its effectiveness, will be developed for module "Structural Inspection & Repair" for students to do active and real time experiential learning of mass site concreting in Laboratory environment. Feedback was collected from the two groups of students after they had completed their FYPs. The very positive feedback shows that students have developed strong competency in obtaining disciplinary and cross-disciplinary knowledge and skills in reasoning through active and project-based learning, collaborative and coordinative team work spirit, and strong skills in report writing and presentation etc., which are required by CDIO syllabus.

KEYWORDS

CDIO Approach, Adiabatic Temperature Rise (ATR) Monitoring System, Workspace Learning, Self-Directed Active Learning, Standards: 5, 6, 7, 8

INTRODUCTION

The Conceiving, Designing, Implementing, and Operating (CDIO), designed to deliver the knowledge and skills needed by industry, is a framework of engineering education curricula for developing next-generation engineers. CDIO provides educators with an important platform in engineering education to establish a new way of conceptualizing teaching and learning, which emphasizes engineering fundamentals as well as all the aspects and skills needed to enable a student's future career. The goals of the CDIO approach are to educate students who are able to (Crawley et al, 2007):

- Master a deeper working knowledge of the technical fundamentals
- Lead in the creation and operation of new products, processes, and systems
- Understand the importance and strategic impact of research and technological development on society

The CDIO's 12 Standards of are very critical to both the curriculum planning and the extensive use of Project-Based Learning for students (Tao N.F., Yoong Y.S., Tan P.S. 2009), especially for those who are doing their Final Year Projects (FYPs) which are part of on-going Research & Development (R&D) projects and use laboratories very intensively will encounter repeated cycles of designing-building-operating systems. CDIO approach for Project-Based Learning has been shown to increase the acquisition of both deeper technical knowledge and nontechnical skills, such as teamwork and communication, and the benefit of which is to retain more students in choosing engineering as their course of study. Interestingly, it has been demonstrated that exposure to Project-Based Learning in the first and second year preferentially retains women (and potentially minorities) in engineering, and exposure in the junior and senior years influences the career choices of students away from non-engineering paths, back to careers in engineering (Crawley et al, 2010).

The successful completion of a R&D project titled Development of Adiabatic Temperature Rise (ATR) Testing System with a duration of 2 years from the beginning of 2016 to the end of 2017 and sponsored by both the Building Construction Authority (BCA), Singapore and Admaterials Technologies Pte Ltd for replacing existing way of on-site mock-up tests and preventing cracks of concrete, improving concrete durability and sustainability, and enhancing construction productivity with involvement of two groups of FYP students using CDIO approach specifically CDIO standards 5, 6, 7 and 8 is a valuable experience which is worth of being shared here.

The project won Singapore Polytechnic R&D Award 2018 and Singapore Ministry of Education Innergy Award 2018. Looking forward, the future plan is to develop a capstone project, which requests students to conceive and design a "recipe" for mass concreting and check its effectiveness by testing concrete samples cast using the "recipe" by the ATR system for module "Structural Inspection and Repair" for students to do active and real time experiential learning of mass site concreting in Laboratory environment. Survey questions were designed and feedback was collected from the two groups of FYP students after they had completed their FYPs. The very positive feedback shows that students have developed strong competency in obtaining disciplinary and cross-disciplinary knowledge and skills in reasoning through active and project-based learning, collaborative and coordinative team work spirit, and strong skills in report writing and presentation.

THE URGENT NEED OF ATR SYSTEM FOR CONSTRUCTION INDUSTRY

The hydration reaction of cement during the course of construction of concrete structures which will develop a large amount of heat with an increase in the concrete temperature. At high temperature (>70°C), ettringite transforms to monosulphate at very early stage of hydration and once the concrete has been hardened, under permanently or intermittently wet condition, monosulphate converts to ettrintgite (Yang R., Lawrence C.D., Lynsdale C.J., Sharp J.H., 1999), which takes up more space than monosulphate from which it forms, and thus causing cracking in concrete. This problem is particularly important in mass concrete structure like pile caps, deep beams, bridge piers and raft foundations where heat dispersions are very small and core temperature can be very high (Yang et al, 1996).

In the current practice in the construction industry, mock up tests are almost always required on high profile and commercial projects by the architect, engineer, or owner, before the commencement of construction work. Collecting, monitoring, recording, and responding to the temperature of the mock-ups along with weather data from the construction site, will allow the construction team to minimize the risk of problems. However, the current method of mock up test takes around two weeks which will delay the construction schedule. Furthermore, the test will increase both the cost of manpower and materials, and in addition, the removal and disposal of the mock-ups up debris of up to 200 m^3 after test will be a problem.

To overcome the above problems, it is necessary to develop a new system for accurate testing and monitoring the concrete temperature, specifically the temperature rise in concrete. Hence a Research and Development (R&D) project was proposed by a team consisting of two academic staffs, two groups of FYP students and an industry collaborator. The project was approved and sponsored by both the BCA, Singapore and Admaterials Technologies Pte Ltd for the development of an ATR testing system to replace current test method.

CDIO APPROACH FOR THE DEVELOPMENT OF ATR SYSTEM

The aim of developing ATR monitoring system is to replace current way of on-site mock-up test and monitor temperature rise in the concrete being used. A trial mixture of the concrete of interest is prepared in lab and its temperature rise is monitored when hydrated under adiabatic conditions in a laboratory environment in advance. Maximum allowable concrete temperatures and temperature differences are measured to ensure that proper planning occurs prior to concrete placement. The term adiabatic refers to a process occurring without any heat exchange between the concrete sample and the surroundings. That means concrete sample cannot suffer any heat loss/gain to/from surroundings theoretically this can be realized by creating a surroundings and keeping its temperature always equal to that of concrete sample.

To achieve the above aim, the ATR system was developed by following CDIO's Conceiving, Designing, Implementing, and Operating sequence of four stages over a period of 2 years with the involvement of two groups of FYP students into the project. The 1st FYP group consisting of 4 students was allocated and involved in conceiving the system specifications and designing the whole system according to the specifications during the academic year 2016. System fabrication (implementing stage) was done by an external professional fabricator. The intended learning outcomes for the 1st group of FYP students were: a) applying disciplinary and cross-disciplinary knowledge and online research to conceive and design a system for monitoring temperature rise precisely in mass concreting; b) teamwork and communication; and c) report writing and presentation. The 2nd FYP group consisting of 3 students was allocated for involving in Operating stage by making lots of concrete samples for testing to monitor adiabatic temperature rise in these concrete samples in order to check and validate system's reliability, repeatability and durability during the academic year 2017. The intended learning outcomes for the 2nd group of FYP students were: a) reasonableness of designing concrete-mix for making concrete samples; b) skills and knowledge of the procedures for making concrete samples to the standards required by local authority; c) teamwork and communication; and d) report writing and presentation.

CDIO APPROACH USED AT DIFFERENT STAGE OF DEVELOPMENT FOR THE INTENDED LERNING OUTCOMES

Project Brief

Before the start of the project, students were briefed to understand the technical requirements of the system, e.g. homogeneity of water, i.e. the water temperature between any two positions in a tank to be designed should not be larger than 0.5°C, and come out specifications for concept design. Students were also briefed the learning activities and tasks to be completed by them for their FYPs. Safety requirements of using Advanced Materials Technology Research Centre's laboratory for tests were also briefed by the technician.

Conceiving Stage

At conceiving stage, students were required to come up with specifications for concept design. A range of activities for active and self-directed learning in classrooms, library and laboratories were arranged for the FYP students to complete. Students were required to do intensive reading of online materials, magazines and books as well as research activities for a write-up of literature review to summarize all the existing systems which can perform similar functions to the proposed ATR system that they were going to develop. Advantages and disadvantages of those existing systems must be listed out, and at the same time, a table showing and comparing all the available functions of those systems must also be provided. At this stage, team work and collaborative learning were strongly encouraged. Peer review of team work was conducted at this stage. Detailed specifications for ATR are shown follows:

1) Single tank design and fabrication with size of 500mm × 500mm × 700mm Height, to provide up to 125 litres of water.
2) Tank: stainless steel 304, 1.5mm thickness, cover, 4 swivel castor wheels, 2 wheels with brakes, 2 manual SS valves.
3) Rockwool insulation with thickness of 2" is placed between the tank and cover
4) Estimated fresh concrete sample volume 20-25 litres (diameter 300 mm, height 300 mm)
5) Electrical accessories and heater design and fabrication, should be able to raise the temperature of water from room temperature 25°C to 95°C, 8 pcs thermocouples, 4 pcs heating elements.
6) Estimation of time needed will be 9 hours for 125 litres of water and 3.5 hours with 50 litres of water from 25°C to 85°C. Ramp rate for water will be ~0.3°C per minute.
7) Circulation (Bubbling pipe and pump or stirrer) used for water homogeneity.
8) Loan control, measurement and data logger system with software program from vendor.
9) Evaluate the homogeneity of water temperature in the tank using 9-point Thermocouple measurement during ramping and during steady-state at 85°C. Homogeneity of water in tank should be within 0.5°C. Repeat experiment with 50 litres, 75 litres, 100 litres and 125 litres of water.

10) Evaluate the temperature homogeneity within the tank during temperature ramp-up & at plateau/steady-state. Homogeneity of water in tank should be within 0.5°C.

Designing Stage

At this stage, students was required to design an ATR system according to the specifications that they came up at conceiving stage. To achieve this aim, FYP students were required to discuss with other students and faculty staff members from School of Mechanical Engineering, School of Electrical and Electronic Engineering, School of Design and School of Info Communication for acquiring cross-disciplinary knowledge on design of system portability, mechanical, electrical and electronic parts, and software for system control, etc. In addition, team work and communication skills were developed through these activities. A few designs were come out by the students for selection. 2D drawings and 3D models were generated using software AutoCAD 2018 and Revit 2018 in computer laboratories according to the specifications. After brainstorming, discussion and comparison, the design shown in Figure 1 and Figure 2 were chosen for fabrication.

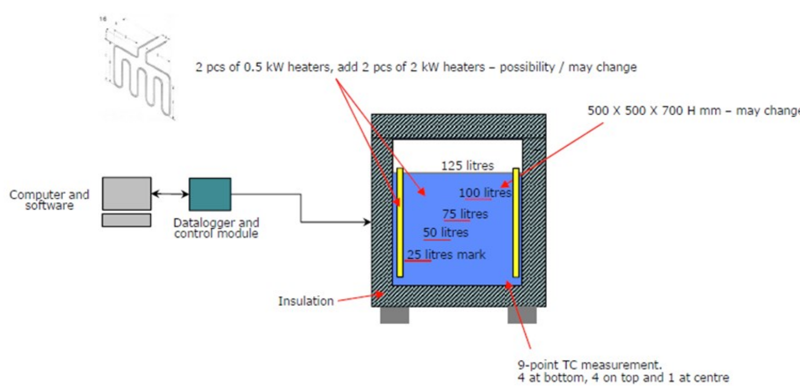


Figure 1. Water tank design

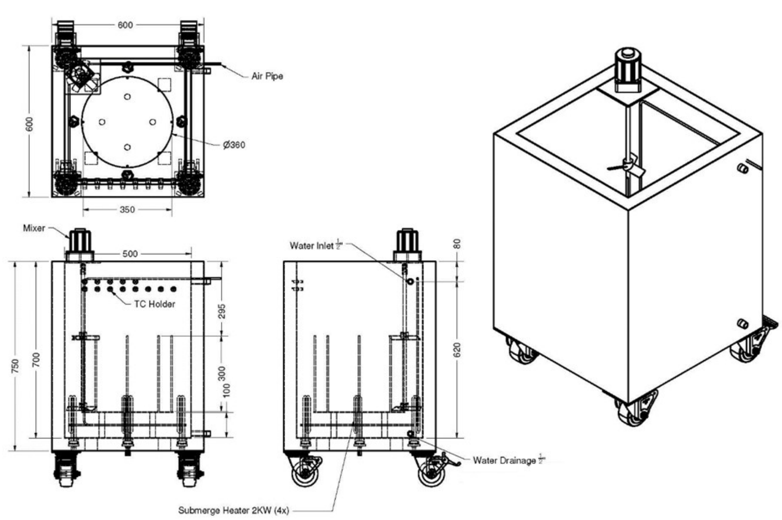


Figure 2. The schematic diagram of the water tank

Implementing Stage

Fabrication of the system and development of the computer software were done by an external fabricator and a software developer respectively according to design drawings and flowcharts provided. Figures 3-5 show the system after fabrication. Students were required to play a coordination role to liaise with the external fabricator and software developer for any queries. CDIO Standards 5, 6 and 7 were used as guidelines for planning the learning activities of students.

Figure 3. Photo of the water tank (left), control panel (right)

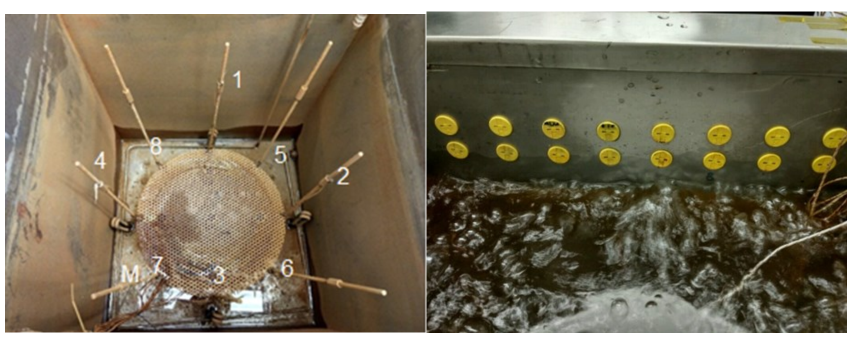


Figure 4. Internal fixture (left) and the internal connecter for the thermocouples (right)

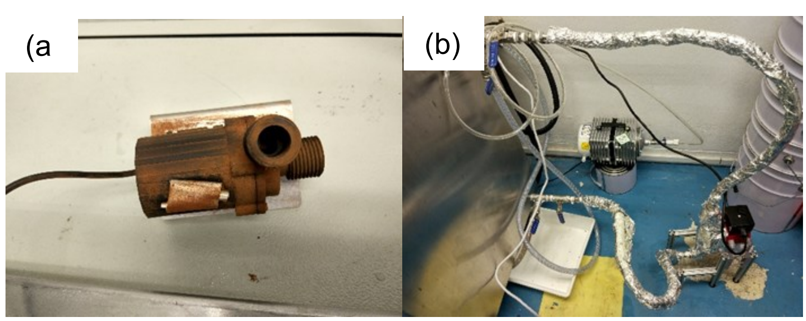


Figure 5. Uniformity improvement of water tank: (a) internal pump, (b) external pump

Operating Stage

At Operating Stage, students were required to make many concrete samples for tests using the fabricated system to monitor adiabatic temperature rise in these concrete samples in order to check and validate system's reliability, repeatability and durability. The 2nd group of FYP students performed these activities during the academic year 2017. At this stage students were required to design many concrete mixes. Table 1 shows an example of a design concrete mix. Concrete samples were then made according to the design mixes. Figure 6 shows two samples made by the students. Tests of samples are shown in Figure 7a. Students were required to collect testing data and process the data collected for the purpose of checking and validating the system as shown in Figure 8 to prove that the design and fabrication of the system is reliable, repeatable and durable.

Table 1. Concrete Mix-Design

Concrete composition	Mass (kg)
Cement	10
Water	4.2
Sand	19
Coarse aggregates	25
Total	58.2

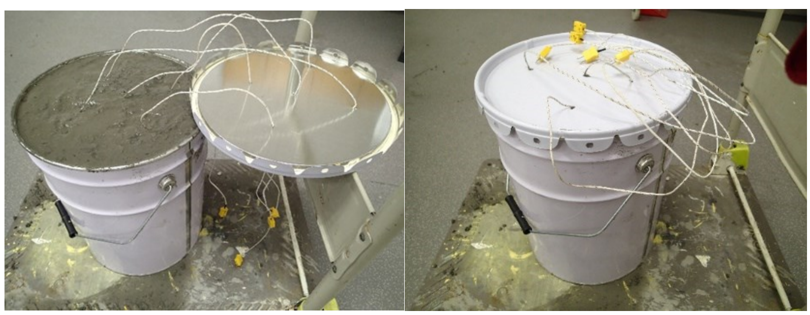


Figure 6. 20L Concrete sample for testing (before (left) and after (right) covering)

As seen from Figure 8 (a), the temperature rise of the four mixes was almost the same. It can thus be concluded that the repeatability of the system is good. The similar rates of temperature change of the four mixes (Figure 8(b)) further indicated the good repeatability of the system. For all the mixes used, the difference in adiabatic temperature rise and peak rate of temperature change were lower than 1.0 °C and 0.9 °C, respectively. Table 2 summarizes the results of the repeatability tests of the system (Li Xiaodong, Tao Nengfu, Huang Hai, Lu Jinping, 2017).

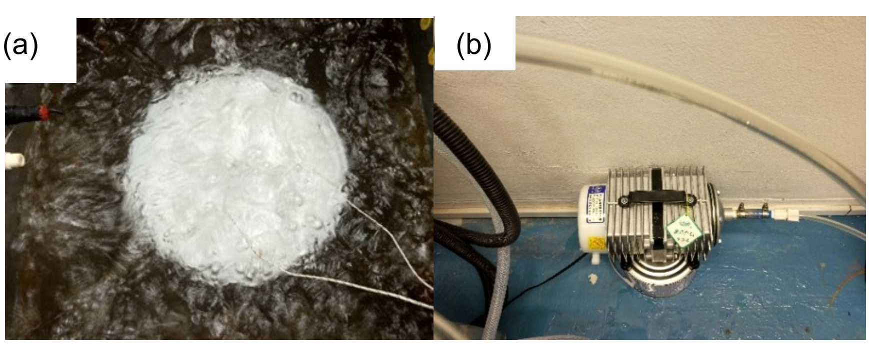
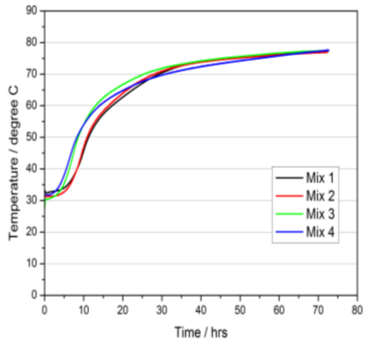
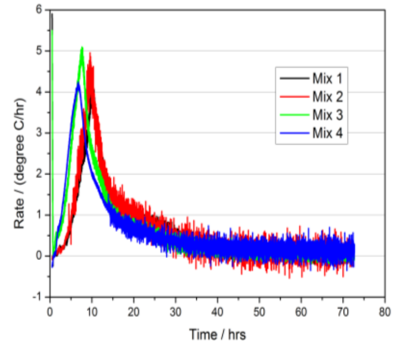


Figure 7. Concrete test setup (a) and compressed air pump (b)



(a)



(b)

Figure 8. Temperature rise of concrete for four mixes (a) and rate of temperature change of concrete for four mixes (b)

Table 2. Summary of test results on repeatability

Mix	1	2	3	4	Max Difference
Adiabatic Temp Rise (°C)	41.10	41.50	42.10	41.50	1.00
Peak Rate (°C/hr)	4.02	4.43	4.92	4.22	0.90

Survey of Student Learning Experience

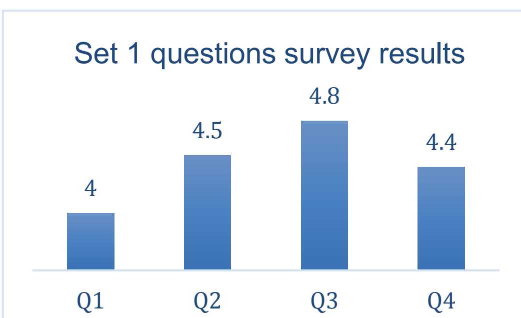
The purpose of conducting survey is to check the intended learning outcomes of the two groups of FYP students through their FYPs. In addition, considering that the 1st group of FYP students involved in conceiving, designing and implementing of the ATR system and the 2nd group of FYP students involved only in operating of the system, therefore two sets of survey questions for the 1st and 2nd FYP group of students were designed respectively. Except Q5, Q1 to Q4 request students to choose a score from 1 (worst) to 5 (best) for an indication of their satisfactory level. Table 3 shows the details of the survey questions.

The survey questions were sent to the two groups of FYP students via emails after they had completed their FYPs in Academic Year 2016 and 2017 respectively and the survey results are shown in Figure 9. By and large the scores for the two sets of questions given by the students are very high which demonstrates the successfulness of using CDIO approach for their FYPs. In particular, for FYP group 1 students, they felt that they had better improvement in communication skills. However for FYP group 2 students, they felt that they had great improvement in building up their capability in collecting and analyzing data.

As for Q5, comments were collected from the two groups of FYP students. Overall their feedback was very positive, which demonstrates that students have developed strong competency in obtaining disciplinary and cross-disciplinary knowledge and skills in reasoning through active and project-based learning, collaborative and coordinative team work spirit, and strong skills in report writing and presentation etc., which are required by CDIO syllabus.

Table 3. Survey Questions

Set 1 (For FYP Group 1 Students)	Set 2 (For FYP Group 2 Students)
Q1: The intensive reading and online research for literature review on the ATR system in what score builds up your capability in conceiving a system and gaining of new knowledge?	Q1: In regard with design concrete-mix for making samples, what score will you be giving for the plan and the way arranged for you in obtaining the disciplinary knowledge?
Q2: At design stage, what score will you be giving for the design skills that you have developed using the iterative design approach as well as the way of seeking consultancy from staff and students from other schools?	Q2: In regard with making concrete samples as well as testing them using the ATR system, what score will you be giving for the learning environment, e.g. the lab space, the small meeting room and the study room provided in terms of conducive learning?
Q3: At the checking and validating stage for the system, what score will you be giving for building up your competency in communicating with industry partners and suppliers?	Q3: In regard with data collecting and analysis of the collected data, what score will you be giving for building up your capability in manipulating, applying, analyzing and evaluating scientific data sets and discovering new knowledge?
Q4: Overall what score will you be giving for the self-directed learning experience that you have gone through this FYP?	Q4: Overall what score will you be giving for the active learning experience that you have gone through this FYP?
Q5: Any other comments on what you have learnt through and benefited from involving in this FYP.	Q5: Any other comments on what you have learnt through and benefited from involving in this FYP.



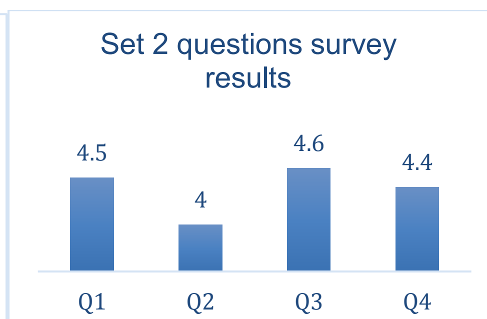


Figure 9. Survey results for set 1 and 2 questions for the 1st and 2nd FYP group of students

FUTURE WORK

ATR system has been successfully developed and can be used for tests of new and green concrete materials. Looking forward, as a 1st trial of using the ATR system for student hands-on learning activities, a capstone project, which requests students to conceive and design a "recipe" and test concrete samples cast using the "recipe" by the ATR system for checking its effectiveness, will be developed for module "Structural Inspection & Repair" for students to do active and real time experiential learning of mass site concreting in Laboratory environment. In long term, more capstone projects using the ATR system for modules such as "Reinforced Concrete Design" and "Construction Materials" can be developed for students to do their study under CDIO framework.

CONCLUSIONS

This paper illustrates in detail how FYP students involved in a R & D project using CDIO approach and successfully developed an ATR system to replace the current way of test for the construction industry.

The intended learning outcomes using CDIO approach were checked by survey careful designed questions, and the very positive survey results show that students have developed strong competency in obtaining disciplinary and cross-disciplinary knowledge and skills in reasoning through active and project-based learning, strong teamwork spirit and skills in report writing and presentation.

In the future, a capstone project will be developed for student to do active and real time experiential learning of mass site concreting in Laboratory environment.

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PROJECTS EVALUATION IN IT ENGINEERING CURRICULUM OF TRA VINH UNIVERSITY

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ABSTRACT

The IT engineer program has been designed in the CDIO approach at Tra Vinh University. Student outcomes of the curriculum are built according to the CDIO syllabus, including the skills: Specialized knowledge; personal and professional skill and attitudes; Communication skills and behavioral attitudes; the ability to form ideas, design ideas, implement and operate in social and corporate contexts. Student outcomes of students are met by building an integrated chain of learning experiences in courses and projects. Moreover, students experience and test their abilities through projects have designed for the 2nd, 3rd, and final years of the curriculum. This article aims to evaluate the student outcomes of the integrated program in the courses and how students use student outcomes to solve a specific requirement through the projects each year. At the same time, this article also analyzes the achieved level of proficiency of the student outcomes in projects each year to evaluate the level of proficiency in students' ability to conceive, design, implement and operate in a social and corporate context. Based on the evaluation, we will review to enhance CDIO skills for students.

KEYWORDS

Projects evaluation, Student outcomes, basic IT project, specialized IT project, Standards: 1, 2, 3, 5, 7, 11, 12

INTRODUCTION

At the national level, Resolution No. 29/2013/NQ/TW on "Fundamental and comprehensive reform of education and training", which emphasizes: "Continuing to innovate teaching and learning methods in a modern direction strongly; promote the activeness, initiative, creativity, and application of knowledge and skills of learners; overcome imposing one-way communication, memorize the machines. Focus on teaching ways of learning, thinking, encouraging self-study, creating a basis for learners to update and renew their knowledge, skills, and capacity development. Moving from studying mainly in class to organizing diverse learning forms, paying attention to social activities, extracurricular activities, scientific research..." (MOET, 2013). At the same time, the Vietnam National University-Ho Chi Minh has introduced many educational framework approaches to improve the quality of Vietnamese education to prepare the following graduates to meet the needs of society, and the applying CDIO standards are used to build an appropriate educational framework for curriculum reform in Vietnamese higher education institutions (Phan et al., 2010). (Phan et al., 2011) has improved the educational framework based on applying and adjusting the CDIO approach, a technical education reform initiative being applied by many Vietnamese universities.

Besides improving the quality of higher education and being recognized by international standards, many universities have turned to international accrediting organizations. Therefore, CDIO stands out as the most suitable educational framework to prepare for international recognition for universities. (Nguyen et al., 2014) described how successfully to implement the CDIO framework for their ABET program accreditation, and (Wah et al., 2015) concludes that CDIO plays an important role in matching the ABET evaluation criteria and accreditation success a short period. Furthermore, (Burbano, 2016) has effectively used the CDIO approach to meet student outcomes (Criterion 3) and the curriculum evaluation process for the continuous improvement (Criterion 4) of ABET.

Since 2014, Tra Vinh University has reformed IT program following the CDIO framework. In 2019, Tra Vinh University became an official member of the CDIO initiative. The program IT following the CDIO approach aiming at an educational environment based on the program educational objectives and student outcomes is clearly outlined thanks to stakeholders' contribution. The IT training program reform process has adopted 12 standards CDIO to guide program evaluation and continual improvement. Standards can be grouped into one or more focus areas: program objectives, curriculum, teaching and learning methods, learning environments, learning assessment, and teaching staff development, as illustrated in Figure 1.

Figure 1. Program evaluation based on CDIO Standards

THE CDIO IMPLEMENTATION

The curriculum is updated from 140 credits to 150 credits applied from the 2020 school year onwards. These include 88 credits of theory, 52 credits of practice, and the remaining 10 credits for graduation. The training program's content is designed with a reasonable structure and sequence, with cohesion between subjects is continuously updated. The program framework consists of two knowledge blocks: General education accounts for 40% of the entire program block, and Professional education accounts for 60% of the remaining block, as illustrated in Figure 2. The percentage of knowledge block in the curriculum framework must be in accordance with the provisions of the training program framework of the Ministry of Education and Training of Vietnam. The IT engineer program of Tra Vinh University has a training period of 4 years. After the second year, students have completed all knowledge block general education courses and core basic technical and assessed by the basic IT project. At the end of the third year, students are assessed through specialized IT projects after completing specialized technical knowledge blocks. After completing all curriculum courses, students will then be required to participate in a postgraduate internship at a company or enterprise for 4 to 12 weeks, respectively. Evaluation results are based on internship results in the company. After that, students access their graduation thesis in 10 weeks to complete their study program. (Shown in Figure 2).

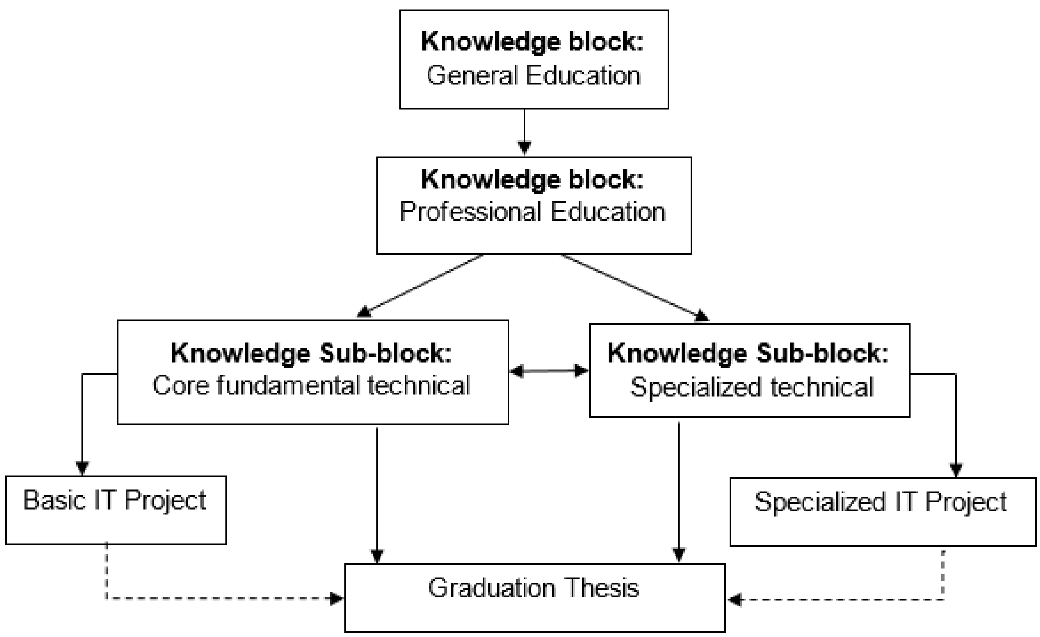

Figure 2. The curriculum structure of IT engineer

To achieve the program quality training, teaching, learning, and soft skills goals. The IT engineer program's student outcomes (SOs) are built on the CDIO model, based on a survey, researching labor market requirements and future development trends. The student's learning progress assessment includes assessing each course and project evaluation of each knowledge block to record each course's learning results, the knowledge block, and the completion of SOs and updated. The student assessment process is done based on SOs, the assessment criteria of the program are identified and converted into the expected learning results of the course (Course Learning Outcome-CLO); from CLO, assessment methods, teaching methods (pedagogical methods), teaching content, and assessment are planned to implement, which are indicated course syllabus. Assessment of course learning is to help students and the University to track students' progress and achievement of CLOs in each course as personal, interpersonal, product, process, and system building skills; at the same time, the assessment results are an essential input for the implementation of continuous improvements to the program (individual subject, assessment methods, teaching methods, supporting resources for teaching and learning). Besides, the project assessment is also a part of the assessment of student learning. The project evaluation is an excellent opportunity to evaluate student's learning experiences in standard CDIO 7 and design-implement experiences in standard CDIO 5. To evaluate the SOs and the level of achievement of the SOs of each type of project, we have designed SOs for basic IT and specialized IT projects according to the SOs' structure of level-3 according to the CDIO syllabus (shown in Table 1).

Table 1. SOs for basic IT and specialized IT projects

Number of SO	**Level-3 SOs**	**Evaluation project**	
		Basic IT Project	**Specialized IT Project**
Block 1: SPECIALIZED KNOWLEDGE AND TECHNICAL REASONING			
1.2.1.	Analyze the requirements of computing problems, designing algorithms, and building appropriate data types	X	
1.2.2.	Apply effectively programming techniques to solve problems	X	
1.2.5.	Presenting the network model and architecture	X	
1.2.6.	Design, install and manage network systems	X	
1.3.1.	Survey, analyze and design Information Systems	X	X
Block 2: PERSONAL, PROFESSIONAL SKILLS AND ATTRIBUTES			
2.2.1.	Information searching and collecting	X	X
2.2.3.	Experimental inquiry	X	
2.4.4.	Self-development of professional knowledge	X	X
Block 3: TEAMWORK AND COMMUNICATION SKILLS			
3.2.2.	Written communication	X	X
3.2.3.	Multimedia communication	X	X
3.2.4.	Presentation and negotiation skills	X	X
3.3.2.	Using technical terms	X	X
Block 4: CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN PROFESSIONAL AND SOCIETAL CONTEXT			
4.2.1.	Setting goals and requirements	X	X
4.3.3	Utilization of knowledge in design	X	X
4.3.4.	Designing components of the system	X	X
4.4.1.	Processes and methods of realization		X
4.4.2.	Realizing the design system	X	X

All students are required to work on two projects according to the attributes shown in Table 2. Students must defend their dissertation in front of the board and be graded on a project defense scorecard with an Assessment Rubric that includes clear criteria and scores.

Table 2. The properties of each project according to the CDIO standards

Group or Individual	Project topic	Products	Adviser	Defense	Time	Reviewer and Assessment
Individual	Lecturers provide topics (Students can propose topics with lecturer's consideration)	1. Report document (Essay) 2. Presentaion slide 3.Application program (Source code)	1 lecturer/ 1 student	Board	4 weeks	2 lecturers

Table 3 (see Appendix) shows the detailed evaluation criteria that lecturers use to evaluate SOs with appropriate CLOs: applying basic and specialized knowledge, technical analysis, investigation, design, tool use, communication skills, project management, and self-study skills. Assessment Rubric will be going to published to students as soon as they choose a project topic. Base on the Assessment Rubric, students identify their assessment criteria and what SOs will be assessed.

RESULT AND DISCUSSION

Project evaluations of different years will have different SOs. There will also be SOs that are replicated in assessing the basic IT project and the specialized IT project. Especially the SOs on personal skills, communication skills, and CDIO skills aim to create training to gradually improve the CDIO skill attainment level for students by years of practice, which will get the higher the level of assessment in the coming years.

The SOs assessed cover 4 blocks of CDIO: Specialized Knowledge and Technical Reasoning; Personal, Professional Skills and Attributes; Teamwork and Communication Skills; and Conceiving, Designing, Implementing and Operating Systems in Professional and Societal Context. Each of the above blocks will be evaluated on some level-3 of SOs, which are described in Tables 1 and 3; besides, the result of the project's evaluation has analyzed by Course Assessment Portfolio software, what we are using to review, and continuous improvement for CLOs for standard CDIO 12.

The evaluation results of the basic IT project

The evaluation results for the basic IT project are presented in Figure 3.

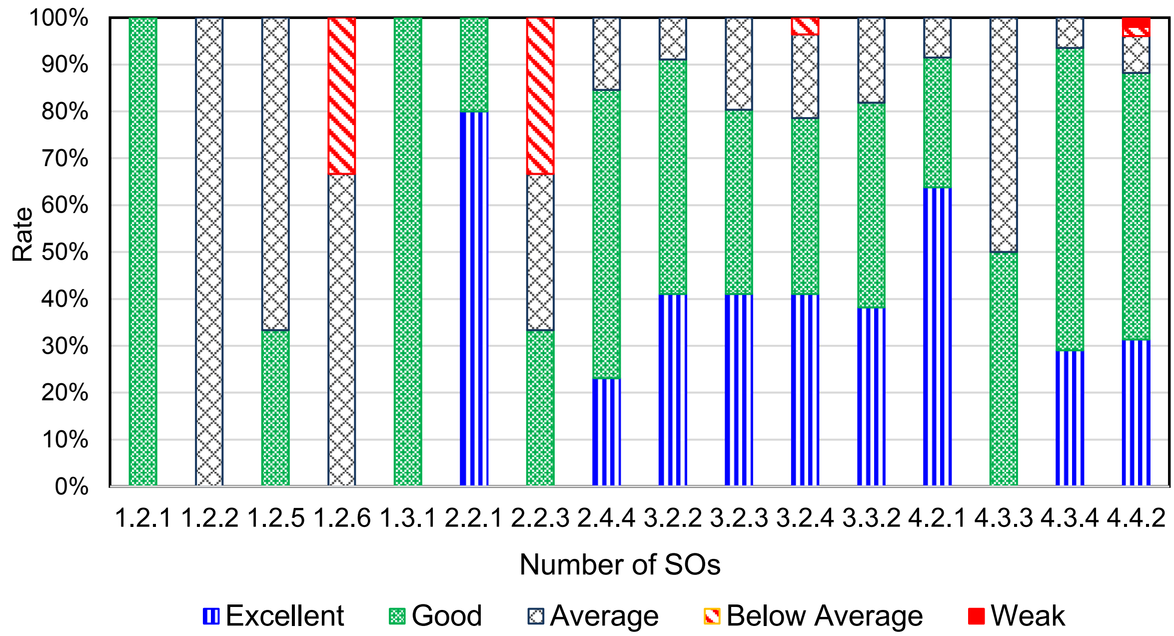

Figure 3: Chart of evaluation results for Basic IT Project

The data presented in Figure 3 shows that the evaluation results of Block 1 in Table 1 (number of SOs from 1.2.1 to 1.3.1) have the highest result as good, no weak. Specifically, the number of SOs 1.2.1 and 1.3.1 achieved 100% is good; the number of SO 1.2.5, with more than 30% of the students attain good results; the rest achieved average marks. Besides, the number of SO 1.2.2 is only average. The number of SO 1.2.6 is about 65% of the students achieving average; the rest are below average. The students' fundamental technical knowledge assessment results were nearly 50% of the students achieved the average grade. Still, nearly 25% of the students did not meet the SO requirements, which is a sign to help us pay attention to the attainment level of CLOs, SO identified in the course syllabus of fundamental technical knowledge block and basic IT project to review teaching methods, assessment forms, assessment contents, course contents. We select the best data for continuous improvement according to standard CDIO 12 to improve the quality of the program.

The number of SOs for Block 2 has the highest rating of excellent with 80%, only 20% achieve well at the number of SO 2.2.1. However, the number of SO 2.2.3 is expected 30% for each level of good, average, and below average. The results number of SO 2.2.3 help us pay attention to the students' experience learning activities or the students' experiential activities are not enough or diverse enough. Approach to accumulating the necessary knowledge and skills for this project at the individual student or project level to consider adjusting the teaching form, assessment method, and project's experiential activities to improve this skill further. The number of SO 2.4.4 has the most satisfactory result (60%), the excellent has 25%, and the average is 15%.

In general, the SOs of Block 3 scored the best. Specifically, the number of SO 3.2.2 has the highest result with 40% excellent, 50% good, and 10% average. The number of SO from 3.2.3 to 3.3.2 accounts for 40% good, 20% average. Only 5% is below average for the number of SO 4.2.4. The number of SO 4.2.1 has the highest number of pretty good students, accounting for nearly 65% excellent, 25% fair, 10% average. The number of SO 4.3.4, 4.4.2 had the same excellent results of approximately 30%, the good one accounted for 60% of each SO; the rest were average, below average, and insignificantly weak. The number of SO of 4.4.2 and the percentage of students who do not achieve this helps us reconsider relevant CLOs in the courses taking on this skill to help students achieve higher results than before.

The evaluation results of Specialized IT Project

The results of the project evaluation are presented in Figure 4. In general, the SOs assessment results of specialized projects are higher than those of basic projects. Specifically, in all SOs, there are students with excellent results. For the number of SOs 1.3.1 and 2.2.1 have 100% of students achieve excellent grades, which is higher than the basic IT Project. The number of SOs 3.2.3 and 4.2.1 have 80% and 90% excellent grades, respectively; the remaining number of SOs have from 35% to 55% excellent. The rest ranked good, and the average type or below accounts is less than 5 - 10%. With the rate of unsatisfactory students (below average and weak), special attention should be paid to training these skills with experiential learning activities and increasing participation in writing and skill activities presented to improve the level of competency achieved for these skill groups so that when assessing the results of the final internship and the thesis, all SOs are at the average level or higher.

Comparing the results of the basic project and the specialized project is shown in Figure 5. Each project type is conducted in different training years to evaluate the evaluation criteria of varying degrees. Some SOs of Block 1 are selected for evaluation differently depending on each project's essential purpose. However, the SOs of Block 2, Block 3, and CDIO Skills are repeatedly assessed on the basic project and the specialized project. This repetitive assessment is now intended to provide practice over and over to achieve a more substantial skill.

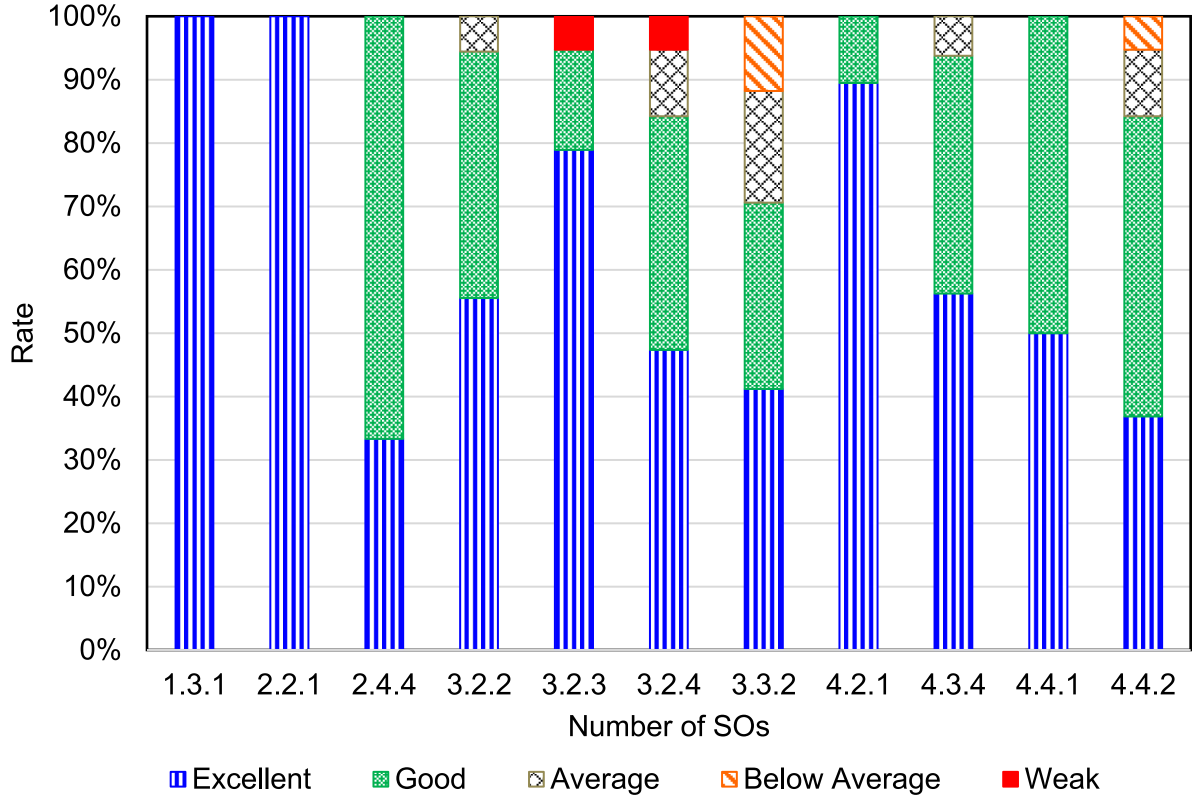

Figure 4: Chart of evaluation results for the Specialized IT Project

Figure 5 shows that most SOs for basic IT projects and specialized IT projects have achieved good and excellent grades. For the average category, the Specialized IT Project has fewer SOs than the basic project. Meanwhile, two SOs are achieving below average and weak for both basis projects and specialized projects. In the end, there is only SO rated ineffective in the basic project. Students are unsatisfactory (below average and weak). We suggest that we consider CLOs in the core fundamental knowledge block, specialized technical, skill proficiency, assessment methods, content assessment, and training methods by engaging students in writing, presentation skills, and experimental activities. To improve the competency achieved for these skill groups to evaluate the final internship results and the thesis, all SOs are from average or highter.

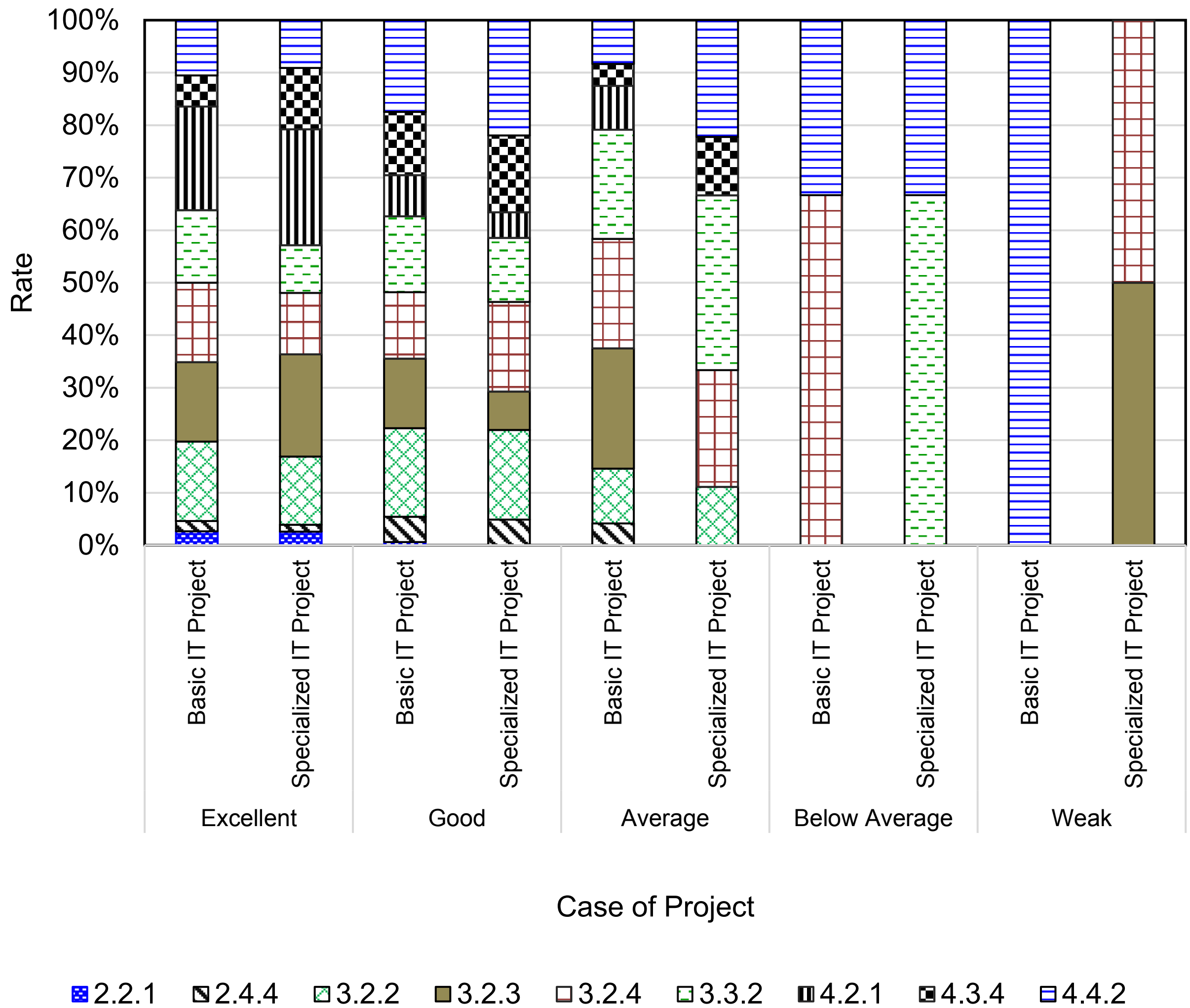

Figure 5: Chart comparing the achievement level of Basic IT Project and Specialized IT Project

CONCLUSIONS AND SOLUTIONS

Through the above analysis and results, the knowledge-based CDIO project courses play an important role in being able to conclude that experiential learning (standard CDIO 7) has an essential contribution to improve student learning outcomes (standard CDIO 11) and update the curriculum framework (standard CDIO 12). Simultaneously, these are the preparatory steps and the specified procedures for implementing an evaluation system for the program by combining evaluation of results and several mechanisms for implementing continual improvement to develop and improve the quality of the program. Usually, the evaluation of an accrediting organization's program is based on two processes. One outer round evaluates the Program Education Objective (PEO) every four or five years. The inner one is performed more frequently to evaluate course results and program conducted annually. However, the curriculum's annual evaluation is sometimes still insufficient information to evaluate because of the student's competence (knowledge, skills, attitude) of a block of curriculum knowledge that has not yet passed fully loading leads to inaccurate measurement of learning outcomes for continual improvement of curriculum. Therefore, designing and building a curriculum on how to manipulate an adequate standard CDIO 2 to define SOs describes what students are expected to learn in each block of knowledge and do after graduation.

Simultaneously, the knowledge blocks' project evaluation process combined with the knowledge modules is used to measure the achieved knowledge block results (CLOs). The CLO describes the knowledge, skills, and attitudes or competencies that students must have or be able to demonstrate after completing the block. The results of the CLOs are then combined with other program-level assessment tools (e.g., student surveys, graduation exams, interviews, course evaluation, ...) to measure the achievement of the SOs at each stage. One proves that we consider Block1's SOs 1.2.1, 1.3.1 (Table 1) to be very important and necessary for further evaluation and improvement. Nevertheless, the course syllabus of the Specialized IT Project lacks SOs 1.2.1, 1.3.1. Therefore, through this article, we can update and supplement the course syllabus of relevant knowledge blocks and Specialized IT Project.

Therefore, TVU's IT Engineer Program is evaluated and continues to develop and improve each sub-curriculum corresponding to each real block to ensure that it brings the necessary learning results for students, accreditation organizations, and industry that they are looking for in the future.

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Appendix

Table 3. Assessment Rubrics for Basic/ Specialized IT Project for mapping CLOs versus SOs

No	Student Outcomes (SOs)	Evaluation criteria (based on CLOs)*	Grade	QUALITY LEVEL				
				Excellent	Good	Average	Below Average	Weak
I. Report presentation format								
1.	3.2.2. Written communication							
II. Introduction								
2.	4.2.1. Setting goals and requirements							
III. Content								
3.	1.2.1. Analyze the requirements of computing problems, designing algorithms, and building appropriate data types (only visible Basic IT Project)							
4.	1.2.2. Apply effectively programming techniques to solve problems (only visible Basic IT Project)							
5.	1.2.5. Presenting the network model and architecture (only visible Basic IT Project)							
6.	1.2.6. Design, install and manage network systems (only visible Basic IT Project)							
7.	1.3.1. Survey, analyze and design Information Systems							
8.	2.2.1. Information searching and collecting							
9.	2.2.3. Experimental inquiry (only visible Basic IT Project)							
10.	2.4.4. Self-development of professional knowledge							
11.	3.3.2. Using technical terms							
12.	4.3.3. Utilization of knowledge in design							
13.	4.3.4. Designing components of the system							
14.	4.4.1. Processes and methods of realization (only visible Specialized IT Project)							
15.	4.4.2. Realizing the design system							
IV. Presentation skills								
16.	3.2.3. Multimedia communication							
17.	3.2.4. Presentation and negotiation skills							

Note: * Describe the specific evaluation criteria in the Basic IT/ Specialized IT Project syllabus

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INTEGRATED CAD AND REVERSE ENGINEERING TO ENHANCE CONCEPTION AND DESIGN

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ABSTRACT

This paper details the adoption of a methodology of integrating CAD with reverse engineering to enhance the conception and design skills of first year engineering students. The students are given an engineered device to reverse engineer via physical deconstruction and redesign via CAD as a group. The aim of administering this methodology is two-fold; firstly, to ensure students from various engineering backgrounds (Mechanical, Electronic, Biomedical and Sport Engineering) reverse engineer devices relevant to their discipline and specifically work on CAD models of these devices to enhance relatability. Secondly, to ensure students appreciate and adopt the underpinning practices involved in the design and conception of engineering devices. As opposed to dictating specifications, the redesign of the device is left at the discretion of the students to encourage a student-centred approach whereby the students take on an active role in the learning process. Additionally, designing and deconstructing the same device as part of a group ensures higher student engagement. This paper demonstrates the efficacy of the adopted approach by providing various examples of students' Reverse Engineering/ CAD outputs as well as assessment statistics. The paper also details the online support provided in addition to the on-site teaching to aid optimum learning in a blended learning environment.

KEYWORDS

Introduction to engineering, reverse engineering, engineering design, CAD, Standards: 1, 2, 3, 4, 6, 8, 11

INTRODUCTION AND BACKGROUND

Reverse engineering is an umbrella term for all the methods undertaken by designers and engineers to create a virtual approximation (parametric computer aided design model) of an existing product (Buonamici et al., 2018). This virtual model can then be reused, optimised, modified and analysed (Zhang, 2003). The process chain of reverse engineering can be broken down into: (i) measurement of correct dimensions (ii) processing measured data and (iii) creation of a computer aided design (CAD) model (Zhang et al., 1999). The industrial use of these techniques target reducing product development/ modification time and reducing production cost (Buonamici et al., 2018).

CAD modelling on its own has a variety of applications in industry and various University level courses, making it an integral part of any Engineering program (Paliokas, 2009, Asperl, 2005). It has been reported that teaching CAD in engineering courses ensures students improve three

-dimensional (3D) thinking, solid modelling and creative ability (Heng-zhen et al., 2002). However, learning CAD is not easy for every student as in addition to requiring computer skills, the students need to have appropriate mental capacity, physical coordination and spatial vision (García et al., 2007). Moreover, student participation and motivation can pose a problem in CAD teaching (Paliokas, 2009). It is crucial to ensure students do not dislike the CAD modelling system or think it is complicated and must be offered enough variety of CAD education to ensure they enjoy acquiring these new skills (Kaminaga, Fukuda & Sato, 1995). As opposed to conventional lectures, some suggested methods such as combination of traditional lecture and video-tutorials as well as providing a variety of projects (Yang, 2019) have improved student motivation and learning experiences (Paliokas, 2009) and are flexible enough to cater to a broad range of learning styles (Lumsdaine & Ratchukool, 2003).

Past research has shown that CDIO standards implementation has enriched the learning experiences of undergraduate students (Deweck et al., 2005). CDIO provides context for beginning engineers to gain appropriate skills to take part in the development of engineering products and processes (CDIO Standard 1) (Brodeur & Crawley, 2005). Working in groups, for instance, encourages the development of inter-personal skills of the students and allows them to gain an integrated learning experience (CDIO standard 2) (Yang, 2019). Additionally, a provision of ample practical opportunities also encourages active learning (CDIO standard 8) (Shimizu et al., 2018). Problem solving and design exercises encourages engagement in engineering practice (CDIO standard 4) (Brodeur & Crawley, 2005). Provision of dedicated engineering workspaces supports and encourages social learning (CDIO standard 6) (Mazini et al., 2018). Moreover, designing curriculum with learning outcomes integrated in them and assessing these allows measuring the expected skills gained by the students (CDIO standard 11) (Brodeur & Crawley, 2005)

In view of the importance of CAD in reverse engineering and the wider engineering industry at large, this paper aims to demonstrate the amalgamation of CAD and reverse engineering at the very start of the students' engineering education journey at Nottingham Trent University (NTU). The module (ENGG10111: Innovation and Engineering solutions) reported here is a year-long module, however the teaching undertaken in the first term only is reported in this work. This paper builds upon the work previously presented (Siegkas, 2020) and the methods adopted have been inspired by similar reported modules (Zu et al., 2012, Deweck et al., 2005, Quist et al., 2017, Yang, 2019) that are in accordance with CDIO standards. Owing to the current pandemic (COVID-19), an aspect of blended learning is also reported here to demonstrate the new norm of Engineering education at NTU and its implementation within the CDIO context.

INTEGRATION OF CAD MODELLING AND REVERSE ENGINEERING

The class enrolled in this module had approximately 200, first-year undergraduate students from a variety of disciplines: Mechanical, Biomedical, Sport and Electronic Engineering. Integration of CAD with reverse engineering to first-year engineering students required significant deliberation and planning. The aim of the planning was not only to ensure a smooth learning experience in a blended environment but instead of focusing on a single engineering discipline, cater to all of them.

Keeping in view that this integration of CAD and reverse engineering had to take place over the course of a single term (8 sessions/ 4 months) and the students were new to CAD as well as reverse engineering, each of these components were planned separately. The dissemination and administration of these components is detailed here.

CAD modelling in a blended learning environment

For the first-year engineering students at NTU, Autodesk's Fusion 360 was taught as the primary CAD tool as has been previously shown (Siegkas, 2020). Owing to the current pandemic, a blended approach to teaching was adopted in which the students undertook 2-hour sessions each alternating week for 4 weeks on-site (in a dedicated design studio) while practice videos were provided to them using NTU NOW ("Nottingham Trent University Online Workspace (NOW)", 2021), the in-house virtual learning environment (VLE) used at NTU. The content covered for CAD is given in Table 1.

Table 1. Delivery of CAD on-site and online teaching

Week	Micro Drone Design with Fusion 360 (on-site)	Practice videos – author provision (Online)
1	Tutorials 1 - 6	Practice video 1
2	Tutorials 7-14	Practice video 2
3	Tutorials 15-24	Practice videos 3 & 4
4	Tutorials 25-27	Practice videos 5 & 6

The on-site sessions focused on a specific project, a provision of the Autodesk design academy and Airgineers as a recommended project to learn Autodesk's Fusion 360. The project – *Airgineers: Micro Drone Design with Fusion 360* (Figure 1) provides detailed tutorials in video as well as text format to conceptualize, design, assemble and test flight of a micro-class drone (Autodesk Design Academy, 2018). The areas of development the project provides are:

1. Understanding parametric CAD modelling
2. Familiarization with the Fusion 360 interface
3. Manipulating part materials and appearances
4. Using various CAD tools (fillets, chamfers, holes) to optimize design in terms of weight reduction with minimal impact on sustaining load.
5. Appreciating the differences in bodies, components as well as assemblies and demonstrating various techniques to move, align and assemble components.
6. Using simulations to test and optimize design.

The project was limited to conceptualizing, designing, assembling and virtual testing while manufacturing the designed components was not undertaken as the main aim of the administering the project was to introduce students to CAD and how it can be used for visual representation.

The tutorials were made available to the students via NTU NOW so they can practice in-class as well as at home. The sessions were supervised by an instructor to ensure students had access to professional support as and when needed.

In addition to the project, short practice videos were also provided on a weekly basis by the module leader. Based on the author's experience, CAD modelling engagement and motivations can be improved by simply ensuring the designed objects are relatable; not all the students necessarily take a liking to a certain project. The practice videos explored designing a variety of other objects to ensure most students could easily find something that interests them all the while getting enough practice on Fusion 360. The practice videos were short and demonstrated how various other creation tools such as revolves, lofts, sweeps, etc. can be used in Fusion 360. The content covered, designed components (Figure 2) and the CAD features demonstrated via the practice videos is given in Table 2.

Figure 1. Assembled 3D model of a Micro Drone (Autodesk Design Academy, 2018)

Table 2. Design creation and CAD features demonstrated via practice videos

Practice video	Design creation	CAD features demonstrated
1	Lego block	Extrudes, construction planes, rectangular patterns, fillet, mirror tool and shell tool
2	Simplified 4 cylinder in-line engine	Revolves, circular/rectangular patterns, assemblies
3	Hammer head	Lofts, guided curves/ rails, offset planes
4	Paper clip	Using canvas/images in CAD, geometry projection, sweep
5 & 6	Simplified variable pitch marine propeller	Fit-point splines, surface modelling, sketch projection, motion study, customizable drawings

Majority of the students appreciated the amount of content made available to them. Most of them preferred the practice videos over the project due to the various creation tools demonstrated in a short amount of time. As the content was released on a weekly basis for the project and the practice videos, most students were able to finish the project sessions and practice the videos in a timely manner and were given ample time in each on-site session to get support or additional help.

Table 3. Milestone or 'Gateways' covered in the reverse engineering project sessions

Session	Gateway
1	Deconstruction proposal
2	Deconstruction and photographed documentation
3	Bill of materials
4	Functional analysis and proposed improvements

Reverse Engineering project

Concurrently with the CAD modelling sessions, reverse engineering sessions which have been reported previously (Siegkas, 2020) were conducted on-site. The students were assigned a group within their discipline (Mechanical, Biomedical, Electronic or Sports Engineering). Each group had (on average) 5 members. The reverse engineering sessions were also conducted for 4 weeks. In this way, the students alternated between CAD modelling sessions and the reverse engineering sessions. Each week a briefing video was uploaded on NTU NOW detailing what the required outcomes of the weekly reverse engineering session are. The reverse engineering project was divided into 4 main 'gateways' which have been given in Table 3. The aim of the project was to allow students to observe a device relevant to their discipline and propose and conduct a deconstruction of the device (Figure 4) into its constituents. This allowed the students to see how the constituent components work together to achieve the desired purpose while also examining the materials and manufacturing processes used to produce the device. The insights gained via deconstruction allowed the students to propose improvements in terms of working principles, structure, materials, manufacturing, and sustainability.

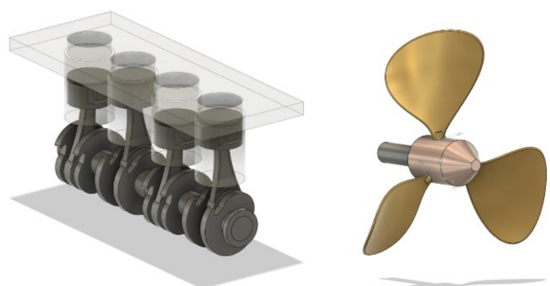

Figure 2. Selected design creations completed in the practice videos (Left) Simplified engine assembly (Right) Simplified marine propeller assembly.

For the reverse engineering sessions, each group was given a device relevant to their discipline. This was an update to the methods reported previously (Siegkas, 2020) and the changes were brought about with a focus on creating a blended learning environment. A laboratory manual was provided to all students to break down the project into milestones or 'gateways' to make it easier for the students to collect data and store it as a formal document. Standardization of the devices meant a deconstruction video for each device could be captured and uploaded on NTU NOW. This video could be viewed by students who were unable to attend the on-site sessions ensuring all students could view and analyse the deconstruction even if they were not physically present. The devices provided are detailed in Table 4.

Table 4. Devices provided to the various engineering disciplines

Discipline	Device
Mechanical Engineering	Mini air compressor
Biomedical Engineering	Digital blood pressure monitor
Electronic Engineering	USB speakers
Sport Engineering	Mini air compressor

Mini air compressors were the chosen device for the Mechanical and Sport engineering group (Figure 3). This simple device is used for sports balls, sports bicycles and even maintaining pressure in motorbike tyres and demonstrates the application of thermodynamics processes and air compression via reciprocating piston movement. It is a motor (or electromagnet) driven appliance that allowed engineering students to see electro-mechanical interface.

A digital blood pressure measurement device (Figure 3) was the chosen device for Biomedical Engineering. The motor driven device used an air pump and multiple air tubes to inflate the cuff for blood pressure measurement.

A USB speaker (Figure 3) was the chosen device for Electronic Engineering. The device works by sending electrical signals to a diaphragm which in turn converts the electrical energy to acoustic energy.

Figure 3. Devices provided to the students for the reverse engineering project (Left) Mini air compressor (Centre) Digital blood pressure monitor (Right) USB speakers. (Amazon, 2020)

Integration method and assessment

There was a single element of group assessment at the end of the term to assess the group's performance. The final submission was a formal group report on the reverse engineering project and had a weightage of 25% of the entire module. Part of this assessment was to produce a CAD model of the reverse engineered device. As the scope of this work is limited to the integration of CAD modelling with the reverse engineering project, readers are referred to the work presented previously by Siegkas (2020) for a more detailed breakdown of the remainder of the assessments for this module.

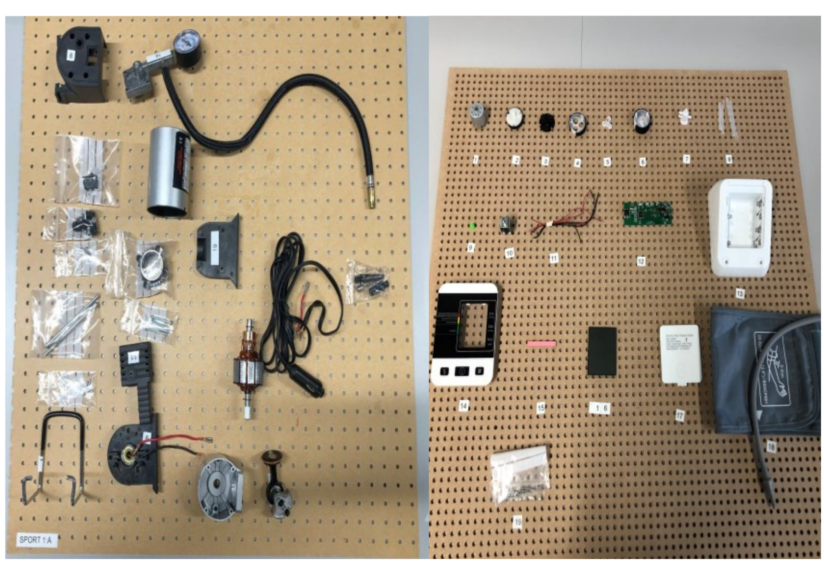

Figure 4. Examples of the deconstructed devices (Student provision).

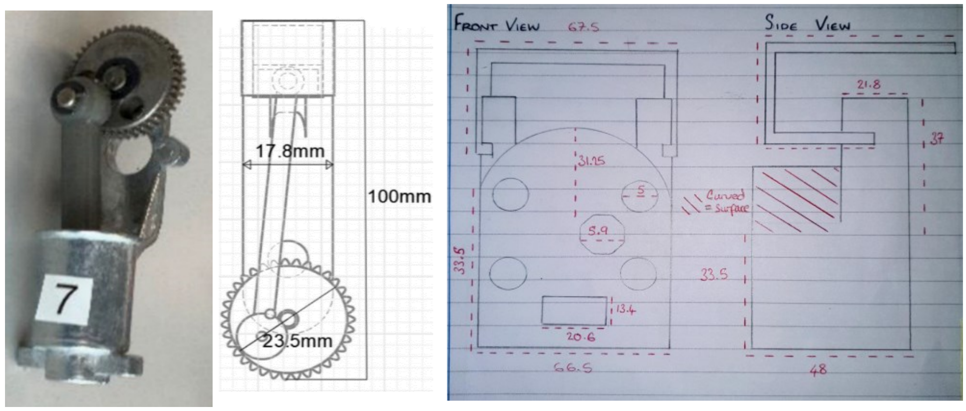

Figure 5. Examples of dimension measurement documentation in the lab manual (Student provision).

As the students started deconstructing their respective devices (Figure 4) in the second session (and had undertaken at least 1 CAD session), they were encouraged to start measuring the constituent components of the device, document this in the lab manual (Figure 5) and start designing a CAD model of each component. A separate section within the lab manual was provided to the students so they could document a photograph of each component along with a CAD model of the component. An example of the CAD model documentation has been presented in Figure 6.

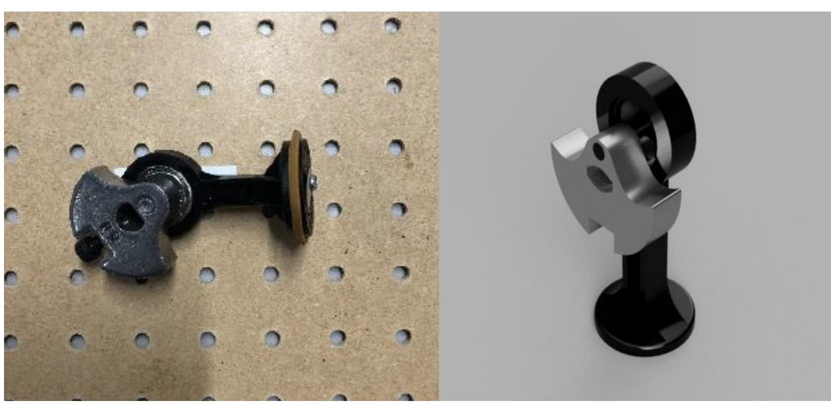

Figure 6. Example of CAD model documentation in the lab manual. (Left physical component (Right) CAD model (Student provision).

Marking criteria & statistics

Once all the reverse engineering and CAD sessions had concluded, the students were given time to compile a formal report on reverse engineering project. As mentioned earlier, CAD modelling formed a part of this report. Once the students had modelled all the components, they were required to assemble the components. Students were required to present their CAD models as general assembly drawings as well as renders of each modelled component and the final assembly. Marks were assigned for presentation of the model and ease with which the reader could understand the assembly of the components. The rest of the report was marked using a generic marking template. The grading criteria and the assigned weightages of each criterion have been presented in Table 5.

Table 5. Marking criteria for the reverse engineering project report

Criterion #	Marking criteria	Weightage (%)
1	General report structure	5
2	Figures and tables	5
3	Abstract	5
4	Introduction & Literature	10
5	Methodology	10
6	Deconstruction	10
7	Functional analysis and improvements	15
8	CAD model	15
9	Discussion	10
10	Conclusion	5
11	References	5
12	Peer assessment	5

The marking and assessment were carried out using online rubrics in NTU NOW, this was to ensure the students received timely feedback as a webpage and to avoid arithmetic errors in marking. Moreover, using online rubrics allowed documentation of marking statistics which are presented in the following sections. Standard NTU grading descriptors and award grades were used (*Grade based marking descriptors*, 2018).

A total of 38 reports were marked and the overall awarded grades and the percentages obtained for each criterion have been presented in Figures 7 & 8, respectively. It is worth noting that the peer assessment has been given full marks for the group report in this feedback as shown by criterion 12 in Figure 8. A separate peer assessment form was provided to the students to assess the performance of their peers and the final grade for each member was assigned via averaged peer assessment scores. Moreover, failing a marking criterion does not lead to failure in the assessment; a failed report must have an overall mark lesser than 40%.

The awarded grades and their implications are based on NTU's grading descriptors (*Grade based marking descriptors*, 2018) where 70% and above signifies a First-Class grade, 60% and above signifies an Upper Second class, 50% and above signifies a Lower Second class, 40% and above signifies a Third class while anything below 40 % is considered a fail.

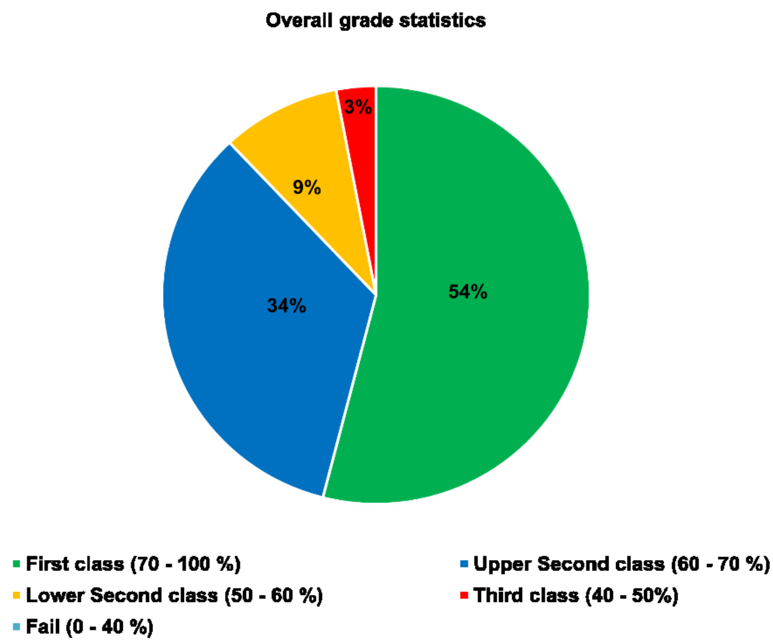

Figure 7. Breakdown of the awarded grades on the reverse engineering project report.

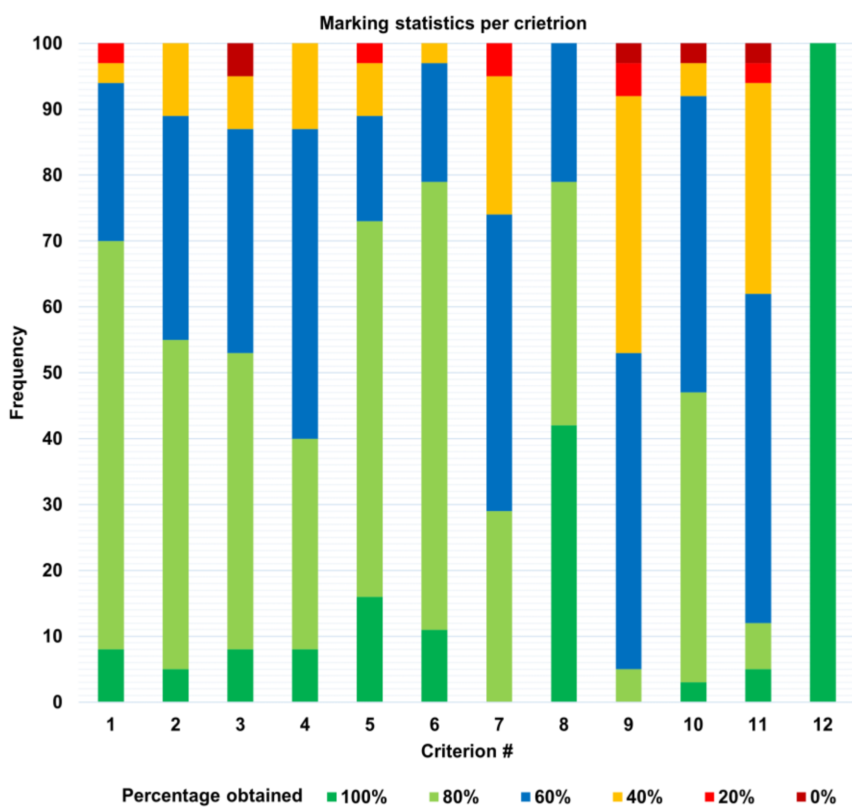

Figure 8. Breakdown of the percentage obtained for each making criterion.

DISCUSSION AND RECOMMENDATIONS

Deconstruction, measurements, research and documentation as a group allows students to appreciate engineering and design processes as well as the value of technical communication. As the students deconstruct and research each component of the device provided to them, they take part in the process of active knowledge construction (Tynjälä,1999). Being part of a larger team promotes social learning as well as the development of inter-personal skills (Yang, 2019). The successful projection of a physical model onto a virtual environment using CAD modelling demonstrates the need for the students to first gain appropriate CAD skills. A variety of practice videos and projects are provided however, these act as guides for various CAD tools as opposed to direct specification of how to create a CAD model of the deconstructed components. This encourages lifelong and active learning.

The delivery of the CAD and reverse engineering sessions in the current pandemic was a significant undertaking keeping in view that these students had never been exposed to reverse logistics or detailed CAD modelling. There were a few limitations in the way CAD was taught in a blended environment:

1. Not all students had access to Fusion 360 at home, on their personal computers. A virtual PC was provided by NTU to allow students to access PCs on campus, remotely and use Fusion 360.
2. The Micro drone design had been demonstrated using an older version of Fusion 360. Some students faced a few minor issues owing to the small differences in the user interface. The on-site sessions allowed these queries to be dealt with right away.

Similarly, given the current circumstances, it was not possible for all students to attend each on-site reverse engineering session. A Microsoft Teams stream was created for each group to ensure the groups could keep in touch and share any files or documentation conducted in the on-site sessions. The weekly online briefing videos ensured the students were up to date with what was taking place in the on-site sessions and the lab manual presented an excellent opportunity for the students for two reasons. Firstly, documentation of each gateway meant the students could easily share their work with each other even if some of the group members could not participate in the on-site sessions. Secondly, the structured documentation of the deconstruction, functional analysis, suggested improvements, CAD modelling and dimensioning ultimately made it much easier for the students to collate the information and compile a formal report. This claim is backed by the fact that none of the students failed the assessment and only 3% managed a Third class grade (Figure 7).

Investigating each criterion in detail (Figure 8) demonstrates that CAD learning was quite successful as it is the grading criterion with the greatest number of groups obtaining 80% or higher (criterion 8 in Figure 8). The student outputs were not only accurate in dimensions, but the photo-realistic renders provided by the students demonstrated an excellent design output when compared to the actual product provided to them (Figures 9, 10, 11).

Figure 9: Photorealistic renders of the designed speakers (left) assembled components (right) exploded assembly (Student provision)

As these are first year students, it must be noted that the grading statistics provide an excellent opportunity to improve certain areas of technical reporting. None of the student groups achieved a first class in the functional analysis and improvements sections nor in the discussions of their reports. It is important to observe that both these sections require the students to go out and actively seek information from quality engineering resources such as journal articles, books, materials and manufacturing database to provide details on function, improvements and back up their claims. A recurrent feature found in most reports was that some scientific claims or recommendations were based on opinion rather than scholarly work. This can be attributed to the student's research skills that are still building up, after all, this is their first term of engineering/ higher education. As this is anticipated, a short report writing online video (provision of the Nottingham Language center) was provided to the students. This does not necessarily help with research; however, it does help them see what is expected of them in a report. A suggestion here would be to run a workshop on research skills to ensure students can develop appropriate research skills at the very start of their respective courses.
During the on-site CAD sessions, it was observed that some students had a lack of relatability with the objects they were designing, such as the micro-drone or even some design creations of the practice videos. However, the integration of CAD with the reverse engineering project meant they would design something they can see, touch and measure. Some of the students would proactively gather their deconstructed items and bring them along to the CAD sessions to design with the components in front of them.

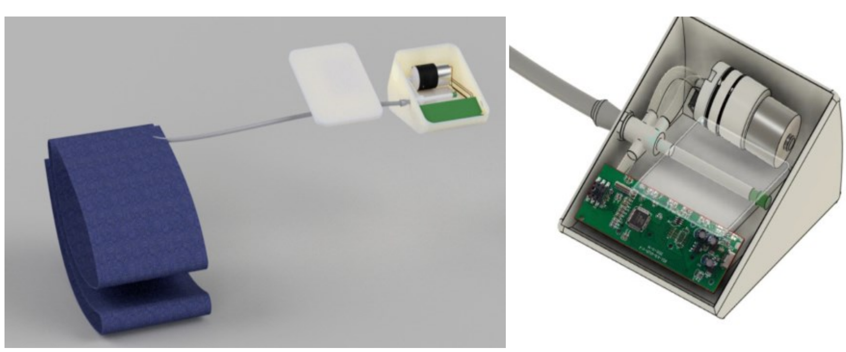

Figure 10. CAD model of the designed blood pressure monitor (Left) Photorealistic render (Student provision)

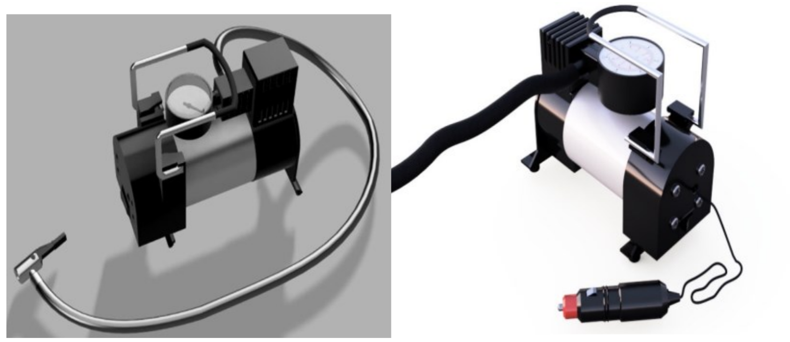

Figure 11. Photorealistic renders of the designed mini air compressor by 2 separate groups (Student provision)

Overall, the students were quite happy with how the projects were run and most of them enjoyed the integration of reverse engineering and CAD modelling. Student feedback seems to suggest that the independence allowed with CAD modelling encouraged creativity and the in-person supervised CAD modelling sessions had a very positive feedback. On one occasion, a student remarked “I enjoy the module especially working with CAD. I quite enjoy the space given by the lecturer, but they are always willing to sit down and explain something when I don't understand or need help.” The virtual development of the reverse engineered device also meant students could not only keep track of their progress but could see their efforts culminating into a finished product by the end of the term. This is backed by a comment made by a student “I like the practical aspect of this module and enjoy the fact I can actually physically see my progress at the end.” Providing the opportunity to students to design something they have deconstructed themselves ensured the student engagement was high throughout the sessions and resonated with a majority of the students, especially the ones who enjoy virtual prototyping as demonstrated by a student comment “I like the practical side of the course for example CAD as I like to physically create something on a digital environment then to make it in real life environment.” The only issue observed with the delivery of this project was the student’s issues with regards to online communication with their group members. The students cited “lack of time” and “lack of online availability” as the root cause. Communication is key for any group work; MS Teams streams were used to mitigate this. Given the number of students enrolled in the course and the high number of student groups, reaching out to check on each group seems counterproductive. Ultimately, with the hopes of the pandemic coming to an end and on-site teaching resuming on a regular basis, communication among the students will markedly improve. In the meantime, a suggestion here would be to breakdown the tasks for students before starting the project and asking each group to assign a member of the team to lead an individual task. As an example, one student in a group could look into the physical deconstruction, one could work on measurement and documentation and all of them could be encouraged to design individual components until finally assembling the model of the device. This will ensure there is a need to share information among the group but more importantly, assignment of tasks will allow students to take responsibility of their own contribution towards the overall group report.

As mentioned in a previous study (Siegkas, 2020), the assessment for the second term for this module is the design and manufacture of a wooden bridge as well as design, manufacture, and optimisation of a support pier. A reasonable proposition would be replacing the bridge and support pier with the redesign and manufacture of some of the components of the reverse engineered devices. The first-year engineering students at NTU have access to a range of manufacturing machines such as laser cutters, 3D printers, CNC as well as manual lathe and drilling machines. The assessment can be built around redesigning and optimising selected components of the reverse engineered device. The optimisation can be in terms of material use efficiency and reliability of the designed components using safety factors as an indicator. The students could start by simply redesigning the components that can be manufactured, followed by optimising the design via simulations on Autodesk's Fusion 360 before finally manufacturing the optimised components using the manufacturing methods available to them. Having observed the student's appreciation of independent learning, opportunity for creativity and the hands-on elements of the module; allowing students to manufacture components that were initially reverse engineered, designed on CAD and optimised using simulation provides an excellent opportunity for year 1 engineering students to go through entire design and manufacture process and works well within the CDIO framework.

CONCLUSIONS

Through the above results and methods, it has been shown that CDIO implementation even in the current atmosphere led to extremely meaningful engineering education. The students worked as a group and were given ample support in a blended learning environment in the form of briefing videos, CAD practice videos, laboratory manual and deconstruction videos. The assessment of skills (CDIO standard 11), the high marks achieved, and the design outputs are a testament of the skills the students gained. The curriculum design and dissemination of project information was done in accordance with CDIO standards 1, 2, 3, 4 and 8 as has been demonstrated via literature and discussion of results. The provision of dedicated design spaces and deconstruction workspaces was also in accordance with CDIO standard 6. The positive feedback of the teaching team involved as well as the observed high student engagement demonstrates an excellent introduction to engineering for the first-year students at NTU.

ACKNOWLEDGEMENTS

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MAXIMISING STUDENT'S LEARNING THROUGH LEARNING ANALYTICS

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ABSTRACT

This paper documents an innovation that is employing the Conceive-Design-Implement-Operate (CDIO) Engineering Education Framework, with a strong emphasis on utilizing the affordances of technological tools – especially the use of Learning Analytics (LA) to diagnose student learning gaps and enhance instructional interventions. The School of Electrical & Electronic Engineering (EEE) implemented an *Assessing Learning in Real Time* (ALERT) strategy for a first-year module (Digital Electronics) involving 19 lecturers and 1211 students, during a COVID-19 circuit-breaker, where students were primarily in a home-based learning mode. ALERT is a joint initiative by the 5 Polytechnics and Institute of Technical Education to create a technology driven framework that incorporate the application of educational technology (EdTech) tools and data visualization software to facilitate learning. The research explored how students experienced specific interventions in real time learning (e.g., the use of readiness tests and an exit poll) through the use of learning analytics (LA) which captures, analyses, and presents student's performance data in a visual dashboard. The findings provided valuable insights into how students experience their online learning in real time, clearly highlighting specific areas of pedagogic focus for enhancing learning effectiveness and efficiency; most notably the importance of well-crafted examples, exercises, and quiz questions to provide opportunities for sufficient practice and feedback. In summary, LA can significantly contribute to the affordances that technology offers teaching professionals in meeting the challenges of today's rapidly changing educational landscape.

KEYWORDS

Learning Analytics, Evidence-Based Teaching, Standards: 8, 11

INTRODUCTION & RESEARCH PURPOSE

Research into how humans learn and what teaching methods work best is enhancing our capacity to design and facilitate instruction from a more evidence-based approach, much like that in engineering and medicine. In this way we can design curriculum and facilitate learning in ways that optimize attainment and engagement opportunities for an increasing range of student cohorts. Furthermore, rapid advances in educational technologies (EdTech) have provided a means to further enhance our capability to make instruction more effective, efficient, and engaging.

For example, developments in Learning Analytics (LA) provide a means to better understand what students are learning (and not learning) in specific terms; hence providing greater insight into what we can do to make our instructional approaches more effective, efficient, and personalized. LA collect, analyse, and present data in highly visual ways about learner's performance, both in real time and for future instruction. The pedagogic benefits include:

1. Identifying learners' understanding and performance levels in designated learning areas and tasks
2. Diagnosing learner's knowledge gaps and misconceptions
3. Customizing and personalization of instruction to individual learner needs and specific conceptual/skill areas.
4. Providing an ongoing evidence-base for future instructional planning.

LA are increasingly providing the capability to extract, dissect, measure and visually present specific critical data relating to students' performances on learning tasks. This highly specific feedback on what and how students are learning (and not learning) enables teaching faculty to design and facilitate more effective and personalized instructional strategies to meet immediate learning needs. The outcome of this learning arrangement is a greater visibility of the learning process in situ, both for students and teachers, and therefore maximizing student learning opportunities in cost-effective ways. In terms of CDIO adoption implementation, such technological affordances, from a sound pedagogical basis, can enhance practice across a number of the standards, especially Standard 8: Active Learning and Standard 11 Learning Assessment. Faculty will be able to provide more personalized and differentiated instruction, as well as specific real-time feedback.

Singapore Polytechnic (SP) adopted the CDIO framework from 2004, as it offered a robust curriculum development approach as well as the necessary flexibility for local customization and creative adaptation. This research supports many of the CDIO standards, especially Standard 8: Active Learning and Standard 11: Learning Assessment.

This paper outlines how the School of Electrical & Electronic Engineering (EEE) employed an Evidence-Based Teaching approach (EBT), LA and other EdTech tools to maximize learning opportunities for students. The specific research questions were:

1. Can the use of LA provide a more precise diagnosis of students learning in real time?
2. Does an EBT approach and selected EdTech tools enhance student learning?

A THEORY OF LEARNING

As Hart (1983) so aptly pointed out:

> …designing educational experiences without knowledge about how human brains learn naturally and most efficiently can be compared to designing a glove without any knowledge of the human hand. (p.4)

The research approach employed was guided by what is now widely referred to as Evidence-Based Teaching (EBT), aptly captured by Petty (2009) who argued that teaching is ready to:

> …embark on a revolution, and like medicine, abandon both custom and practice, and fashions and fads, to become evidence-based (cover page).

EBT constitutes an emerging 'science of learning' or what Sale (2015) refers to as *Pedagogic Literacy*. He outlined and illustrated 10 cognitive scientific principles (Core Principles of Learning) that underpin effective learning design and teaching. For brevity here, these are only listed for identification (please refer to the original text for extended explanation):

1. Motivational strategies are incorporated into the design of learning experiences
2. Learning goals, objectives and proficiency expectations are clearly visible to learners
3. Learners prior knowledge is activated and connected to new learning
4. Learning is enhanced through multiple methods and presentation modes that engage the range of senses
5. Content is organized around key concepts and principles that are fundamental to understanding the structure of a subject
6. Good thinking promotes the building of understanding
7. Learning design utilizes the working of memory systems
8. The development of expertise requires deliberate practice
9. Assessment is integrated into the learning design to provide quality feedback
10. A psychological climate is created which is success orientated and fun

Another major focus of EBT owes much to the definitive work of Hattie's (2009). He synthesized over 800 meta-analyses of the influences on learning and was particularly interested not just in what factors impacted learning, but the extent of their impact - referred to as *Effect-Size*. Effect size is a way to measure the effectiveness of a particular intervention to ascertain a measure of both the *improvement* (gain) in learner achievement for a group of learners and the *variation* of learner performances expressed on a standardised scale. By taking-into-account both *improvement* and *variation* it provides information as to which interventions are most worth having.

Hattie firstly identified the typical effect sizes of schooling without specific interventions, for example, what gains in attainment are we likely to expect over a one-year academic cycle? Typically, for students moving from one year to the next, the average effect size across all students is 0.40. Hence, for Hattie, effect sizes above 0.4 are of particular interest. As a baseline an effect size of 1.0 is massive and is typically associated with:

- Advancing the learner's achievement by one year
- A two-grade leap in GCSE grades (this is a national examination system in the UK and is used for illustration of enhanced attainment in a formal assessment context).

Table 1. depicts some of the high effect methods employed in the overall instructional design strategy. These are used strategically in relation to meeting the desired learning outcomes and the identified student need in different learning contexts.

Influence	Mean Effect Size
Formative Evaluation to teachers This is where teachers take action to get feedback on their teaching and act on it	0.90
Feedback Students getting feedback on their work from the teacher, peers, self, or others.	0.73
Teacher - Student Relationships Building rapport and trust and positive expectations	0.72
Whole-class interactive teaching (including Direct instruction) A specific approach to active learning in class, which is highly teacher led, but highly active for students. This involves summaries reviews and a range of active learning methods, including questioning	0.81
Metacognitive Strategies Explicit teaching and use of metacognitive strategies (e.g., conscious planning, monitoring, and evaluating of thinking and learning)	0.69
Challenging goals for students Goals that students can meet through effort on their part – specific as possible; meaningful to the students involved	0.56

While there has been considerable debate on the applicability of EBT to engineering education (e.g., Borrego & Streveler, 2015), and a rapidly growing body of literature on what is referred to as Engineering Educational Research - the latter is still considered an emerging field of enquiry (Reynolds & Dacre, 2019). Hence, the extent to which engineering education is best served by so-called signature pedagogies (Schulman, 2005) is still an area for further research. The EBT perspective outlined here is perfectly compatible with the notion that different fields of study lend themselves to different pedagogic blends in terms of 'best method use'. However, this does not detract from the usefulness of a generic framework of cognitive scientific principles underpinning the design and facilitation of learning experiences in engineering education.

The Impact of Feedback on Student Learning

As noted above, Hattie recorded an averaged Effect Size of 0.73 for feedback (i.e., students getting feedback on their work from the teacher, peers, self, or others).
There are many interrelated aspects that contribute to the high impact potential of feedback on learning. Nicol & MacFarlane-Dick (2006), as quoted by Sale (2020), in synthesizing the research literature suggest the following seven principles:

Good feedback practice:

1. helps clarify what good performance is (goals, criteria, expected standards)
2. facilitates the development of self-assessment (reflection) in learning
3. delivers high-quality information to students about their learning
4. encourages teacher and peer dialogue around learning
5. encourages positive motivational beliefs and self-esteem
6. provides opportunities to close the gap between current and desired performance
7. provides information to teachers that can be used to shape teaching (p.203)

Furthermore, effective teachers - just as they adjust their communication style to different student personalities - also adjust their provision of feedback accordingly based on students'

need in different contexts. For example, Hattie and Yates (2014) suggest that novices require more specific task-related corrective feedback, to be gradually replaced with more process feedback as they become increasingly proficient and self-regulated in their learning.
What this means is that initially, feedback will focus on detecting errors in what students are doing on a task, and then help to reduce and eventually eliminate these errors. Such feedback will include showing students what went wrong, examples of correct performance and ways to improve on these types of learning tasks. Process feedback is more focused on how the students are tackling the tasks given, such as their thinking (e.g., analysing, comparing, making inferences & interpretations, evaluating) and the learning strategies they are using. In providing feedback it is often the case that both aspects are needed, and this is where the teacher's judgement and skilful action are most impactful. As students become increasingly proficient, feedback is usually more focused on their abilities to monitor and evaluate their own learning, both at cognitive and affective levels (e.g., metacognition). Questions of how much feedback and the frequency of feedback, as with all aspects of differentiated instruction, will depend on the situation and learners' readiness. As Hattie (2012) summarized:

> The key is the focus on decisions that teachers and students make during the lesson, so most of all the aim is to inform the teacher of student judgements about the key decisions: 'Should I relearn…Practice again…To what?' and so on. (p.143)

How technology can enhance feedback

Firstly, it is important to emphasize that technology per se does not enhance feedback; that must be provided by the teacher in ways framed earlier. In the more generic sense, as Moroder (2013) discovered from her experience:

> Technology does not make learning more engaging or meaningful. A great lesson does this…technology can make it more effective and efficient.

However, as identified earlier, LA enables the capability to rapidly capture, segment, and personalize student's performance data in highly visual forms. In this way faculty can see, in real-time, the 'what' and 'how' of student learning. This enables us to identify the specific feedback needed for individual students, as well as the best instructional interventions to address learning difficulties. In summary, LA can make the process of assessment much more efficient and, therefore, potentially more effective.

METHODOLOGY

The methodology involved quantitative and qualitative data on the student learning experience during the project intervention strategy. This involved the following activity stages:

1. Students do a Socrative readiness test before online class time.
2. Students take a 30-minute time-tabled schedule covid-19 formative assessment (cFA) from the Blackboard learning management system, which is completed on their webcam enabled laptop at home. Staff invigilate them using the ZOOM platform, which is a web-based video conferencing tool that allow users to meet online with video. In this way, staff can see and monitor all students on the same screen for cFA invigilation throughout the assessment.

3. Students complete a 1-minute short exit poll before class end (Microsoft TEAM synchronous session)*
4. Lecturers analyze the data further via Power BI Dashboard and plan for intervention actions.

This process is illustrated in Figure1: Real-Time Student Feedback Process by EEE.

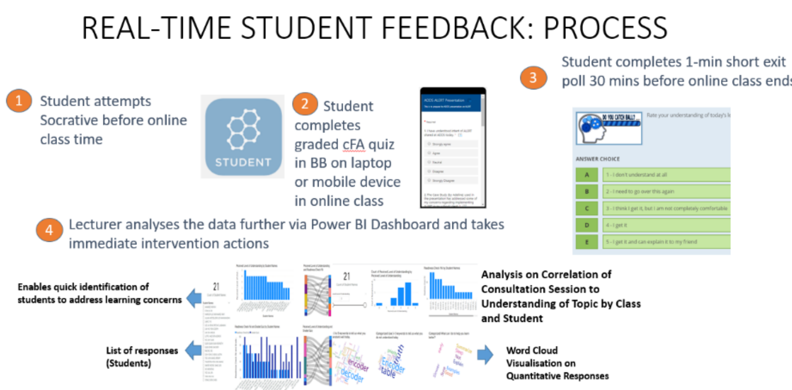

Figure1: Real-Time Student Feedback Process by EEE

A sample of the Socrative readiness test and exit poll is attached in Annexes 1 & 2.
Student feedback on these learning activities was collected by means of a short questionnaire comprising the following 3 question items:

1. How useful did you find the pre-class quiz before you attend the DE1 lesson?
2. How useful did you find the EXIT POLL conducted 30 mins before the DE1 lesson end?
3. Please help us to teach you better? You are free to speak. The sky is the limit.

RESULTS

Figure 2. Sample Dashboard of Pre-class quiz results, and Figure 3. Sample Dashboard of Exit poll results are examples of dashboards of student performances from which facilitating lecturers can interact with students, diagnose areas of learning difficulty in situ, and change aspects of their pedagogic strategy in response to perceived student learning needs.

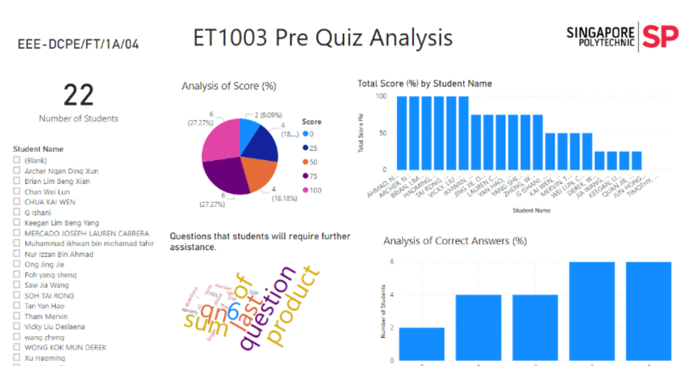

Figure 2. Sample Dashboard of Pre-class quiz results

The key purpose is to identify if students require further help with questions, so that faculty can adjust the lesson plan to address student's need.

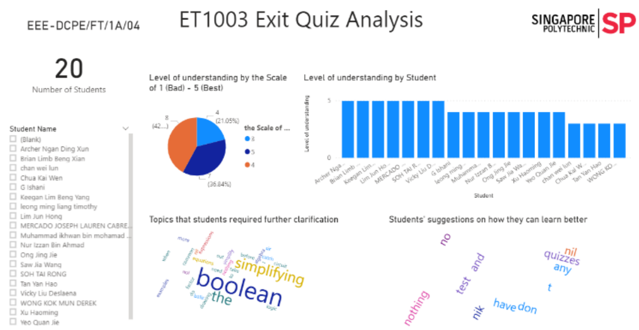

Figure 3. Sample Dashboard of Exit poll results

The key purpose is to assess students' perceived level of understanding of the lesson in real time in order to help faculty identify which topics required further clarification, and use some of the remaining time in addressing this learning need.

The student's experience of this learning intervention is depicted in the pie charts in Annex 3: Summary findings from Questions 1 & 2. They also show comparisons between the author's student group and the aggregated responses from the other student cohorts.

These findings revealed notable differences in the percentages of positive and negative responses between the two samples. For example, the percentage of 'extremely' and 'very-useful' for the pre-class quiz was 64% for the author as compared to 36% for the aggregated 'other lecturers'. Similarly, for the Exit Poll, the comparable figures were 44% as compared to 31%.

Making comparisons between the author's group and the aggregated responses of other faculty raises methodological issues. Most notable, the author had employed an EBT approach for several years on a number of research projects, while there was no clarification on the approaches used by other lecturers, apart from the broad methodology outlined prior. However, the differences invite questions for future pedagogic planning and practice in this intervention and teaching effectiveness generally.

Question 3 was an open response item to capture student's experiences, perceptions, and feelings in their own words. This data revealed that certain specific aspects of instruction are notable in terms of how students perceived usefulness to learning, which has implications for improving future practice.

Firstly, it was interesting to note that 6 responses across the samples suggested that for some students, there was a strong preference for the face-to-face classroom learning environment, starkly illustrated by one student who wrote, " I WANT GO SCHOOLLL… that is wayyy…better." However, 9 responses suggested that other students were at least satisfied and had no specific negative responses. Terms used include, "All is fine for me" and "Great so far". It is likely, in this context, that some lecturers were doing *things* that worked better than what others were doing. As there was no stratification of the faculty involved, it is not possible to make inferences and interpretations concerning faculty differences in terms of training or other specific demographic characteristics, beyond the engineering context.

However, much pedagogic value can be derived from the student's responses to features they liked (and did not like) concerning instructional practices during the intervention. For example, 29 responses for improvement related to more and better focused questions, examples, and activities in which they could do sufficient practice with feedback to build understanding. Also, several negative comments related to a lack of clarity and/or too fast a pace in the instruction provided. Illustrative comments include:

“We need more practice”; “Go through more examples”; “Give us answer key to check”
“Do a brief run-through of each chapter every lesson”; “Ask more questions”.

IMPLICATIONS FOR PRACTICE

The results from this research intervention offer practical insights into how best to utilize LA and other EdTech tools to maximize student feedback. These are summarized in the following sub-sections:

Applying EBT in planning and evaluating instruction

While comparisons between the student feedback cohorts are not generalizable, they do support the notion that an EBT approach may further advance the affordances of technology interventions – whether specifically using learning analytics or EdTech tools generally. The higher scores in the quantitative data of the author’s cohort is further supported by the qualitative data in terms of the student feedback. Very few negative responses were identified e.g., only 2 responses relating to the pace being fast).

Pedagogically, EBT enables instructional design and facilitation to more effective, efficient, and engaging. This facilitates a common pedagogic language among faculty for improving, customizing, and differentiating of instruction for more students. It also enables better utilization of EdTech affordances in maximizing different aspects of the learning process.

Identifying more precisely and efficiently student learning gaps and misconceptions

This is a clear affordance of using the LA technology employed. From the dashboard, it is possible to identify students who are having difficulty with specific concepts and topic areas, as it will flash out their names and results. While cFA is only viable on weeks 3, 5, 11, 13, 15, 17, the immediate intervention using the readiness quiz result and exit poll collected each week makes the aggregated data useful for future lesson design, as it enables more specific inferences and interpretations on the ‘what’ and ‘how’ of student learning, and why they may not understand certain topics.

The dashboard data enables monitoring student’s learning in real time, offering more insightful diagnosis of learning problems and facilitating effective pedagogic interventions. This is illustrated below in Table 2.

Table 2. Summary Examples of Using the Dashboard for Real-time Pedagogic Interventions.

Learning situation	**Specific examples from using Power Bi visualisation**	**Action**	**Pedagogic Impact**
Students may not prepare well for pre-class activities	A student only scored 50% in the pre-class quiz, and rated himself 3/5 in the perceived level of understanding.	Provided feedback to make him aware of his lack of understanding and encouraged him to persist and ask questions during the 30 minutes of Q&A time before end of class.	He subsequently scored 9/10 in his cFA2 and scored 93% in cMST.
Students perform poorly in pre-class tests but over-estimates own level of understanding	A student scores 25% in the pre-class quiz, but rated himself 4/5 in the perceived level of understanding.	Intervened with task specific questions and positive feedback, monitoring performance over the duration of the instructional period.	This student subsequently scored 62% in the cMST, which he may have failed without a focused intervention.
Students may be over-confident and not do sufficient preparation for a lesson or test	A student scored 50% in the pre-class quiz and rated himself 4/5 in the perceived level of understanding. He scored 9/10 in his cFA2 quiz.	He asked concept questions, which I thought he understood.	He only scored 31% in cMST. It may be that he did not prepare well, or should have been monitored more fully. Hence need to be aware of this in future.

This enables faculty to quickly identify weaker potentially at-risk of failure students, and take immediately take appropriate action to remediate the learning gaps/misconceptions with an instructional intervention(s). This can be done in a number of ways (e.g., uploading a new video using another scenario/example to explain the concept; additional self-assessment quiz questions; answer templates providing specific feedback).

Initially, the faculty conducted the exit poll 5 minutes before the end of the lesson, downloaded the results after class, then analysed the student's responses in order to gain evidence-based insight into their learning strategies, notable areas of difficulty, and how best to adjust the instructional strategy for the upcoming lessons. However, the faculty subsequently decided that it would be pedagogically more useful to do the exit poll 30 minutes before the class end, as they can then act upon the emerging data in real time; hence do 'on the spot' analysis of the student learning, and better identify what seems to be the immediate concerns relating to key conceptual understanding. They then can use some of the remaining direct contact time to do focused remediation based on this timely feedback.

Similarly, while the use of Socrative has a number of pedagogic affordances, including activating prior knowledge, key concept testing and feedback, and aiding instructional planning, it only enables 1 public room for 1 lecturer. As some faculty teach more than one class there is the problem of collecting data for the readiness check test and exit poll. At present, the faculty have to manually key in the data for cFA. Also, due to the circuit breaker, faculty had limited time to prepare for the ALERT project, but still have to quickly shift from face-to-face lessons to home-based learning and integrate ALERT into their lesson plans.
It is essential, therefore, to use an EdTech tool that automates cFA, as this will be time- saving for large scale implementation, which is a necessity for the 'ALERT' process to be viably implemented. Once achieved, faculty can monitor students' virtual classroom learning experience to better inform instructional approaches and module design; hence providing a systemic enhancement for real-time student feedback to maximize learning.

Enhancing teacher expertise through professional development

While this intervention involved 19 faculty from the School of EEE, there is a need to upscale professional learning to the wider institutional context, developing what Hargreaves and Fullan (2012) refer to as 'Professional Capital' (i.e., institution-wide faculty expertise).

In the present context of SP, we are developing what Hargreaves and Fullan (2012) refer to as 'Human Capital' (i.e., individual faculty achieving high expertise), and there has been sharing of learning through staff development briefings and workshops. Hence, we are also achieving some degree of what Hargreaves and Fullan frame as 'Social Capital' (i.e., increasing numbers of faculty sharing their work and learning experiences).

For the future, we need to continue building on the social capital presently being developed, to foster a learning community committed to achieving sufficient Professional Capital for the longer-term educational goal of building a unified pedagogic and EdTech approach to learning and teaching – irrespective of delivery mode.

LIMITATIONS OF THIS RESEARCH & FUTURE LEARNING

As previously noted, while the author had considerable experience in applying the principles and practices of EBT, there is limited knowledge of how well-prepared other faculty were in this intervention; hence, comparisons between the two samples are limited. Also, while questions 1 and 2 elicited quantitative feedback on the usefulness to learning of the readiness test and exit poll, they were limited in terms of unpacking the student experience in more precise forms that would have enabled a deeper understanding on how students were learning. Furthermore, as student performance was not measured, their perceptions cannot be corroborated in terms of meeting specific learning outcomes. This was, in part, the result of time pressure to get the intervention moving quickly in the context of rapid school closure. These are areas for future improvement in both methodology and scope.

SUMMARY

This paper has outlined a pedagogic intervention, initiated in response to the challenge of providing effective and efficient online learning in the COVID-19 pandemic. The research suggests that learning analytics, when employed from an EBT approach, can play a significant role in using EdTech affordances to maximise student learning outcomes.

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Annex 1: A sample of the Socrative readiness test.

3. Which of the following is digital quantity?

- A The amount of money in a wallet
- B Temperature of a room
- C Depth of a submarine in the ocean
- D Blood pressure

4. What is the positional value of digit '7' in decimal 27.1?

- A 1
- B 10
- C 100
- D 1000

5. Convert 1011_2 to its equivalent decimal value.

- A 10
- B 11
- C 12
- D 13

List any questions from the above that you will require further assistance.

Annex 2: A sample of the Exit poll

1 of 2

Rate your understanding of today's online lesson in the Scale of 1 to 5.

5 - I get it and can explain it to my friend
4 - I get it
3 - I think I get it, but I am not completely comfortable
2 - I need to go over this again
1 - I don't understand at all

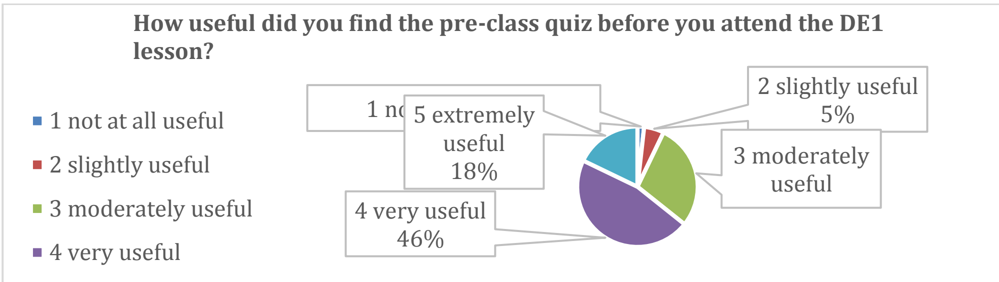
- A 5
- B 4
- C 3
- D 2
- E 1

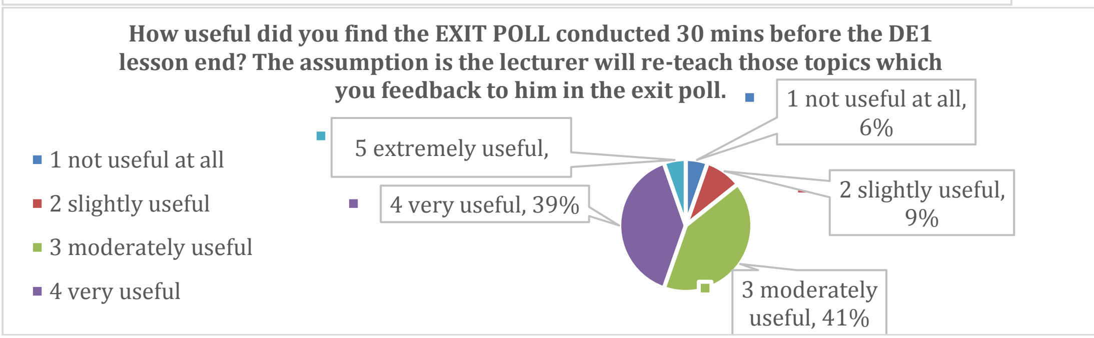
2 of 2

Use 3 to 5 **keywords** to tell us which topic you need further clarification.

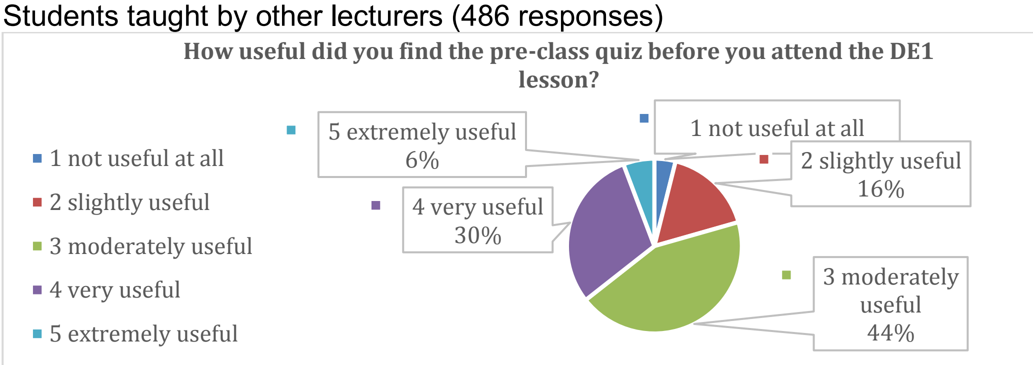
Annex 3: Summary findings from Questions 1 & 2.

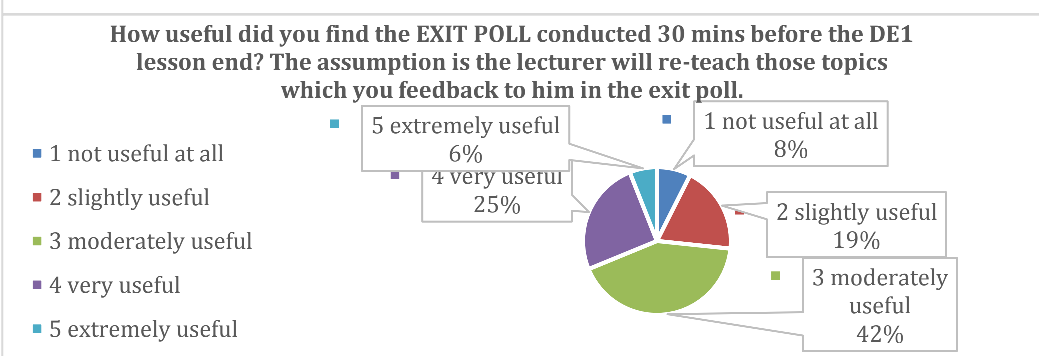
Students taught by the author (56 responses)





Students taught by other lecturers (486 responses)





BIOGRAPHICAL INFORMATION

Mark Wan is a Specialist (Teaching and Learning) / Senior Lecturer from School of Electrical and Electronic Engineering, Singapore Polytechnic. He consistently looks for different ways to bring his classroom to life, utilizing an evidence-based approach to pedagogy and experimenting with EdTech tools to better engage and support student's learning. His research interests include active learning pedagogies, blended learning (flipped classroom), and enhancing students' intrinsic motivation in engineering modules.

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WORK-BASED LEARNING MODEL TO DEVELOP SELF-DIRECTED LEARNERS IN OPTOMETRY EDUCATION

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ABSTRACT

This paper evaluated the effectiveness of the work-based learning (WBL) model to develop self-directed learning skills in optometry education. WBL model was introduced to Year 2 Diploma in Optometry students at Singapore Polytechnic. Fully integrated workplace learning was incorporated, where students were exposed to “real patients” (members of public) with various eye conditions. Students learned to merge theory with practice, knowledge with experience during their hands-on clinical training sessions at the Singapore Polytechnic Optometry Centre (SPOC). Content of four core optometry modules, self-directed learning skills and professional dispositions were integrated and delivered through flipped learning, in-class activities/discussions and clinical training sessions. Hands-on optometric examination skills were imparted through clinical training by following patients from each of the major clinical disciplines, across different venues of care under supervision (integrated clerkship). Through interaction with peers and public patients, students also develop their generic employability skills. Development of self-directed learning skills and professional dispositions were based on self-reporting by the students and observation by adjunct lecturers who were independent third party observers. Students take on an active role in this model since most activities of learning were student-led and faculty- or supervisor-guided. WBL model was shown to be a faculty- and resource-intensive model which worked better with smaller cohort size particularly for practical oriented modules and during clinical training. The learning points from WBL model can be adopted for similar resource-intensive engineering courses.

KEYWORDS

Work-based learning, self-directed learning, optometry, Standards: 1, 2, 3, 6, 7, 11, 12

INTRODUCTION

Self-directed learning (SDL) is a skill that has received increasing attention in recent years, particularly in the context of Singapore education. The Ministry of Education, Singapore, in its Masterplan for Information and Communications Technology in Education, has identified self-directed learning as one of the key 21st century skills that should be nurtured in our students. Broadly, SDL refers to the process in which an individual learner is motivated to take responsibility and accountability for his/her own learning (Knowles, 1975). Despite many approaches and models in the literature, there is general agreement that SDL involves the following iterative stages, irrespective of the specific terminology employed:

- Planning Learning
- Managing Learning Performance and Process
- Reviewing and Evaluating Learning

The use of learning strategies to develop the true understanding of learning how to learn is of significant importance in developing the SDL skills of students (Sale, 2019).

Work-based learning (WBL) is an educational model that provides students with real-life work experiences where they can apply academic and technical skills and develop their employability skills (e.g. confidence, communication, teamwork and other work-related attitudes and behaviours) (Alkema and McDonald, 2014). It is a series of educational courses which integrate the school or university curriculum with the workplace to create a different learning paradigm or an integrated learning experience. WBL deliberately merges theory with practice, knowledge with experience, and acknowledges the intersection of explicit and tacit forms of knowing (Raelin, 1997a, Raelin, 2010, Flanagan et al., 2000). Work-based learning prepares students for employment and is driven by the educational institution (IAL, 2016).

The WBL model also provides a scaffold to support a functional "*community of practice*" wherein students learn by directly co-managing patients under the supervision from lecturers or mentors. WBL is a learner-managed rather than academic-managed learning *(Eraut, 2004) and therefore inculcates self-directed learning.* WBL model using integrated clerkship is practised in medical schools such as Duke NUS Medical School, Singapore and Harvard Medical School, USA. It was reported that students in the integrated clerkship perform equally in terms of academic performance to peers in traditional block clerkships, but display enhanced patient-centered attitudes and develop meaningful relationships with faculty (Duke-NUS, 2020).

Work-based learning model in the Diploma of Optometry course at Singapore Polytechnic

The Diploma in Optometry (DOPT) curriculum aims to produce optometry graduates who are equipped with technical skills and generic skills like communication/presentation skills, organisational skills and independent learning skills. The course aims to produce professionally competent optometrists to serve as primary eye care practitioners who are self-directed and life-long learners (CDIO Standards 1 & 2).

Work-based learning (WBL) was first introduced to Year 2 Diploma in Optometry (DOPT) students at Singapore Polytechnic (SP) in semester one of the 2018/2019 academic year (AY1819S1) in response to curriculum review and pedagogy for the profession. It was introduced to address gaps in the traditional system of block rotations; in recognition that existing clinical training can be structurally and educationally enhanced and last but not least, to inculcate SDL. This WBL model is based on the integrated clerkship model in which the entire academic year of the student consists of a longitudinal, integrated curriculum approach to learning & assessment (Duke-NUS, 2020). The students get concurrent integrated exposure to multiple disciplines in a fully-equipped leaning space in preparation to employment (CDIO Standard 3). According to a study conducted by Hirsh et al. (2012), integrated clerkship model encourages the development of students' learning and improves students' professionalism.

To date, no study has been done on the impact of this teaching approach in optometry. This paper evaluated if WBL model could develop SDL skills and improve the academic performance in optometry students.

DESCRIPTION OF WORK DONE

The annual DOPT course intake comprises three classes of students of approximately 20 students per class. WBL model was first introduced in AY1819S1 for year 2 students, on an opt-in basis. To date, WBL model has been implemented for two cohorts of optometry students, 'WBL cohort 1' in AY1819S1 (the pilot cohort, one class only, n = 20) and 'WBL cohort 2' in semester one of the 2019/2020 academic year (AY1920S1) (all three classes, n = 65). The other two classes in AY1819S1 were taught using traditional/conventional mode of lesson delivery (n = 42) and they are called 'Trad cohort'. Students from AY1819S1 cohort are the cohort 1 and the students from AY1920S1 cohort are the cohort 2.

Four core optometry modules, CP3065 Binocular Vision, CP3066 Contact Lens, CP3056 Ocular Disease 1 and CP3062 Clinical Optometry 3 were traditionally offered in block rotations. Students in WBL cohorts were taught using WBL teaching approach (integrated curriculum), where the delivery of technical knowledge from the core modules where integrated along with development of professional dispositions (CDIO standard 3) (Figure 1). Professional dispositions such as confidence, independence, motivation, analytical, communication and interpersonal skills are the skills and attitude that optometry graduates should possess to be work-ready. Fully equipped learning space, the Singapore Polytechnic Optometry Centre (SPOC) provided the required integrated learning experiences (CDIO Standards 6 & 7). All students, regardless of the cohort they belonged, were taught the same content and same means of assessment were applied throughout the semester.

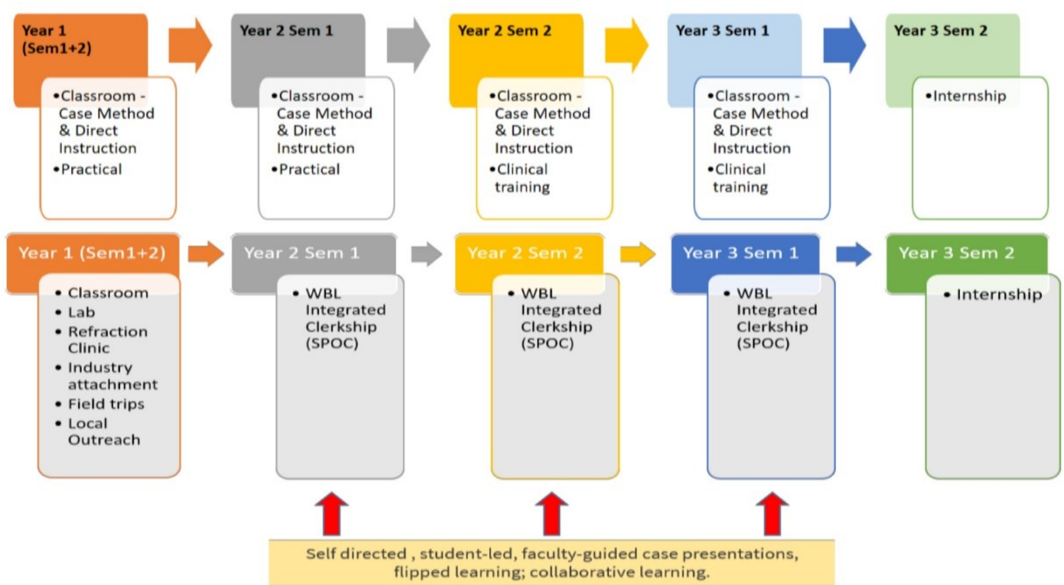

Figure 1. Traditional/conventional teaching approach (top) versus WBL (integrated clerkship) teaching approach (bottom) in Diploma of Optometry.

The traditional approach imparts learning of the core modules in blocks and students are led by teachers at each step. In the WBL, integrated clerkship approach the student learning takes place in an integrated manner as they follow the patients and perform history taking, the various clinical techniques and devise the management plan by following members of public at SPOC. The different components that guide the students in this self-directed learning in this model are the flipped learning materials, e-portfolio, practical and clinical training, peer teaching, simulated cases, and reflection journal. The lecturer's role is to facilitate the process and give formative feedback in this approach. The different components of our WBL model and how they are mapped with SDL skills are summarised in Table 1.

Table 1. Mapping of WBL components with SDL skills

WBL teaching plan	**Mapping of WBL with SDL skills** (Sale, 2019) a) Planning Learning b) Managing Learning Performance and Process c) Reviewing and Evaluating Learning
Fully integrated workplace learning This was in the form of clinical training in the SP Optometry Centre (SPOC) where students were exposed to 'real patients'. The learning was supported by learning materials such as **e-portfolio** and **workplace portfolio. Weekly grand rounds** were conducted to review their learning. During clinical training, students were trained to apply the technical knowledge and skills learnt to examine patients at SPOC under supervision of their lecturers and adjunct lecturers. They were trained to integrate theory and knowledge from their learning into practice. **Four core modules** taught in the semester were integrated through various **in-class activities** including **Case method**. Content delivery was done through "**Flipped learning**". Students were paired during clinical training to facilitate **peer-tutoring** to develop inter-personal & collaborative skills. **Assessment** of student learning was carried out using variety of methods. Regular feedback was given for their portfolio entries, during clinical training, during class activities (formative assessment). Summative assessments included written and practical tests, end of semester exams,	**E-portfolio:** Students were guided to plan and complete the questions by a given timeline *(a).* It helped them to make sense of the concepts and put the pieces together *(b).* Feedback for improvement (formative) given by lecturers on the activity sheets & students' progress in mid- and end-semester assessments *(c).* **Workplace portfolio:** Students were exposed to 'real patients' to apply their skills and knowledge in an 'authentic workplace' (SPOC). This helped the students to apply what they learnt in a different situation, to continue review, evaluate and extend their learning *(c).* **Weekly reflection journal:** Students reflected on what they have learnt and how to improve. (*c).* **Weekly grand rounds:** Students discussed cases they have seen during clinical training, to review and evaluate their learning and seek improvements *(c).* **In-class activities/case discussions**: These were 'student lead, faculty guided'. Students were involved in active learning and they took ownership of their own learning *(b)*. **Through flipped learning:** Students planned their learning and went through the online material prior to the in-class discussion. Readiness check was done to track student's preparedness *(a).* **Peer-tutoring:** Students learn from each other and this inculcated collaborative learning and developed their inter-personal skills *(b).* **Case method:** Students discussed and reviewed different cases, facilitated by lecturers *(c).* Case

oral presentations and class participation. (CDIO standard 11) Students were given different **simulated case scenarios** to expose the students to a variety of cases that they may not see during their clinical training. Students were trained to complete a task, activity or problem in an off-the-job situation that replicates the workplace context. This was done through various online software and also during face-to-face sessions.	method helped to develop few important skills essential for optometrists: Communication/collaborative skills, Adaptability/resilience, Sense making (include analytical-, critical-thinking and problem solving skills) and Empathy/Ethics. These are also important skills for lifelong learners. **Simulated practice:** This encouraged students to 'think out of the box', a variety of cases that they are not exposed to at SPOC were covered using this approach. This helped to review, evaluate and extend their learning *(c)*.
Practical sessions: The work-based learning at SPOC was complimented by practical sessions for the four core modules, external placements and field-based activity such as community service.	**Practical sessions**: Students watched videos and prepared before they performed the practical in lab and completed their activity sheets *(a).* Practical tests were administered at the end of the semester to track students' performance. These sessions imparted all practical training covering the core clinical skills required in the later stage *(b).*
Internship: The students were sent for a seventeen weeks internship to eye clinics, hospitals, optical outlets, and ophthalmic/contact lens companies at the end of semester 1 of year 3 of their study.	**Internship:** Students were placed in a real workplace environment with minimal guidance from lecturers. This helped them to review, evaluate and extend their learning *(c)*.

To evaluate if the above WBL model had developed SDL skills, professional dispositions and produced good academic performance in the Optometry students, the following were investigated:-

***i. Student survey (SS)**:* This was administered on WBL cohorts 1 and 2 as well as the Trad cohort. The survey was designed using a 5-point Likert scale. It consisted of six questions and focused on the following attributes: SDL, skills development, learning experience and professional dispositions/soft skills.

***ii. Focus group interview (FGI)**:* This was done to gather more in-depth views from students in WBL cohorts 1 and 2. In total 40 students were randomly selected, 12 students from WBL cohort 1 and 28 students from WBL cohort 2. The questions were designed to understand the student's viewpoint on how the WBL model helped them develop SDL and the other professional dispositions such as confidence, communications skills, motivation to learn more, analytical skills, independence and to think out of the box.

***iii. Adjunct lecturer survey (ALS)**:* Adjunct lecturers served as an independent ("third-party') observers on students as they were only involved during clinical training at SPOC. ALS was gathered on WBL cohorts 1 and 2 as well as the Trad cohort. A survey was designed using a 5-point Likert scale and consisted of 3 questions, focussing on the following attributes: interpersonal skills, critical thinking and traits of an independent optometrist.

iv. Final module score (FMS) in four core optometry modules*:* In order to study the academic performance of students. FMS was retrieved from the database on WBL cohorts 1 and 2 and compared with the Trad cohort. Final module score (summative assessment), includes assessment score of various components such as written assessments for application of concepts learnt, teamwork, class participation, communication and practical skills.

This study was granted exempt status by the Institutional Review Board of Singapore Polytechnic.

STUDY FINDINGS

Student survey (SS)

Twenty responses were collected from WBL cohort 1, 34 responses from WBL cohort 2 and 31 responses from Trad cohort. Mean ± SD score was 4.1 ± 0.3 for WBL cohort 1, 4.1 ± 0.2 for WBL cohort 2 and 4.1 ± 0.1 for Trad cohort which were very similar (Table 2).

Table 2**.** Students' evaluation on work-based learning and traditional teaching approach

Survey Questions	**WBL cohort 1 (n=20)**	**WBL cohort 2 (n=34)**	**Trad cohort (n=31)**
SS1. I am becoming a self-directed learner (meaning to some extent, you are able to study, reflect, evaluate/derive meaning)	3.7	3.9	3.9
SS2. WBL/the teaching approach helps me to develop useful optometry skills and knowledge, so can be work-ready.	4.3	4.1	4.0
SS3. WBL/the teaching approach helps me to develop useful professional soft skills and knowledge.	4.1	4.1	3.8
SS4. WBL/the teaching approach helps me to enhance my clinical practice knowledge.	4.4	4.4	4.2
SS5. WBL/the teaching approach provides engaging learning experience.	4.2	4.2	4.1
SS6. Overall, I have developed more confidence in my optometry skill sets and knowledge.	3.9	3.9	4.2
	4.1 ± 0.3	4.1 ± 0.2	4.1 ± 0.1

Rating scale: 1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly Agree

Students reported that the teaching approach they underwent enabled them to become self-directed learners (SS1, indicated "agree" or "strongly agree", 65% in WBL cohort 1, 70.6% in WBL cohort 2, 74.2% in Trad cohort), it helped them to develop useful optometry skills and knowledge, to be work-ready (SS2, 100% in WBL cohort 1, 82.3% in WBL cohort 2, 74.2% in Trad cohort), it helped them to develop useful soft skills and knowledge (SS3, 85% in WBL cohort 1, 91.2% in WBL cohort 2, 67.7% in Trad cohort), it helped them to enhance their clinical practice knowledge (SS4, 100% in WBL cohort 1, 91.2% in WBL cohort 2, 87.1 in Trad cohort), it provided them an engaging learning experience (SS5, 90% in WBL cohort 1, 91.2% in WBL cohort 2, 87.7% in Trad cohort) and overall, they developed more confidence in optometry skills set and knowledge (SS6, 80% in WBL cohort 1, 73.5% in WBL cohort 2, 80.6% in Trad cohort).

Focus group interview (FGI)

FGI results were encouraging especially from both WBL cohorts, especially WBL cohort 1. All 12 of them (100%) from cohort 1 and 96% from WBL cohort 2 agreed that WBL model helped to develop the three main iterative stages for SDL, that they were able to plan, manage and review their learning. It was observed that students managed their learning by following different strategies and regularly reviewed their learning. 83% of students from WBL cohort 1 and 54% from WBL cohort 2 agreed that WBL trained them to be self-directed learners. Again, 100% of the students from both cohorts agreed that this approach helped them to better apply their skills and knowledge to examine and manage patients as WBL provided early exposure to clinical training and allowed more hands-on at SPOC. Most of the students from both cohorts reported that WBL helped develop their professional dispositions in terms of confidence, communication skills, motivated to learn more, analytical skills and independence. However, they felt that WBL did not really help them ‘think out of the box”.

Adjunct lecturer survey (ALS)

For adjunct lecturer survey (ALS), 11 adjunct lecturers responded on WBL cohort 1 as well as the Trad cohort, and 6 adjunct lecturers responded on WBL cohort 2. The Mean ± SD score for the 3 cohorts is shown in Table 3.

Table 3. Adjunct lecturer evaluation on WBL cohorts 1 and 2 and traditional cohort

Survey Questions	**WBL cohort 1 (n=43)**	**WBL cohort 2 (n=35)**	**Trad cohort (n=90)**
AL1. This student exhibit interpersonal skills (e.g., build rapport with the patient, etc.)	4	3.5	3.5
AL2. This student exhibit critical thinking (e.g., suggest appropriate clinical test, etc.)	3.8	2.8	3.2
AL3. This student exhibits all traits of an independent optometrist (e.g. minimum guidance needed, etc.)	3.6	2.3	3.1
	3.8 ± 0.2	2.9 ± 0.5	3.3 ± 0.2

Rating scale: 1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly Agree

According to self-rated opinions of the ALS, the adjunct lecturers felt that WBL cohort 1 exhibited remarkably good (> 50% indicated “agree” or “strongly agree”) interpersonal skills (AL1, 74.4%), critical thinking (AL2, 72.1%) and had displayed traits of an independent optometrist (AL3, 65.2%). However, they felt that WBL cohort 2 was not as good. WBL cohort 2 only exhibited reasonably good interpersonal skills (AL1, 54.3%) but the other two attributes namely critical thinking and traits of an independent optometrist (AL2 and AL3) were not well exhibited (AL2, 28.6% indicated “agree” or “strongly agree” and 42.9% indicated “disagree” or “strongly disagree”; AL3, 17.1% indicated “agree” or “strongly agree” and 60% indicated “disagree” or “strongly disagree”). As for Trad cohort, it was better than WBL cohort 2 but poorer than WBL cohort 1. Trad cohort exhibited reasonably good interpersonal skills (AL1, 54.3%) but the other two attributes namely critical thinking and traits of an independent optometrist were again, not well exhibited (AL2, 43.3% indicated "agree" or "strongly agree" and 36.7% indicated "neutral"; AL3, 35.6% indicated "agree" or "strongly agree" and 44.4% indicated "neutral").

Final module score (FMS) in the four core optometry modules

On comparing the final module score (FMS) in the four core modules, students performed differently in different modules. (Figure. 2)

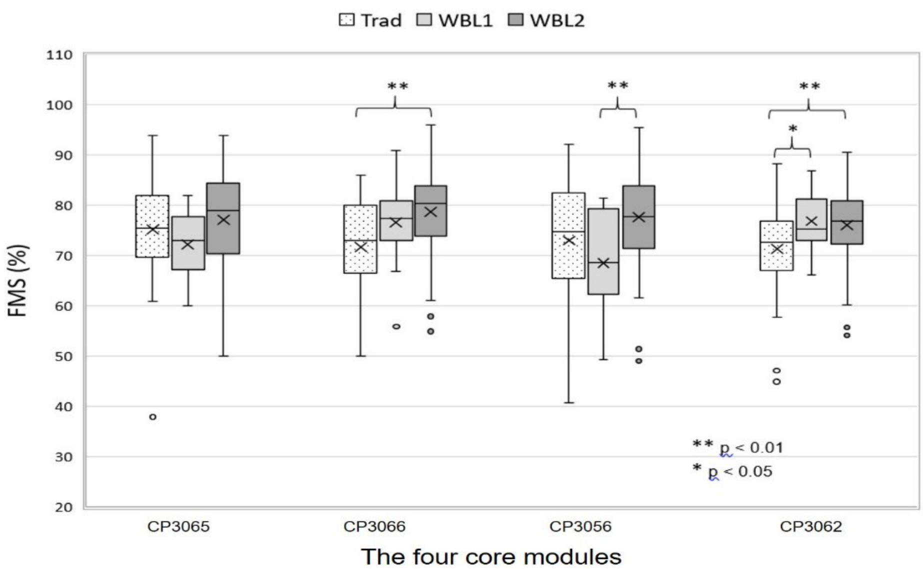

Figure 2*.* Box plots showing final module score (FMS) performance for WBL cohorts 1 and 2 versus traditional cohort in the four core modules.

As compared to Trad cohort, WBL cohorts 1 and 2 performed significantly better with higher mean marks in CP3062 (76.9 in WBL cohort 1, 76.2 in WBL cohort 2 vs 71.4 in Trad cohort) (one-way ANOVA, $p < 0.05$). For CP3066, only WBL cohort 2 did better with significant higher mean marks (78.8 vs 71.7 in Trad cohort) (one-way ANOVA, $p < 0.01$). For CP3056, WBL cohort 2 (mean marks: 77.7) did better than WBL cohort 1 (mean marks: 68.5) (one-way ANOVA, $p < 0.01$) but no differences were found when comparing with Trad cohort. Lastly, for CP3065, no significant differences were found in any of the cohorts studied (Figure. 2). So it is shown that WBL did not work consistently in all four core modules.

DISCUSSION

SDL had clearly been demonstrated in the WBL cohorts through the student survey (SS) and focus group interview (FGI). The adjunct lecturer survey (ALS) and final module score (FMS) in the four core modules showed that the WBL cohorts 1 and 2 performed differently which will be discussed below.

From students point of view (through SS and FGI)

Through FGI, students reported that WBL helped them to develop the three main iterative stages of SDL. They were able to plan, manage and review their learning and took ownership of their learning which is one of the key features of SDL (Sale, 2019).

Students liked the integrated learning experience of hands-on approach, merging theory with practice, the early clinical exposure to ‘real patients’ and learning by mimicking the lecturers/supervisors in a real workplace at SPOC. All of them indicated that WBL helped them to better apply clinical skills and knowledge to examine and manage their patients.

WBL helped develop their professional dispositions in terms of confidence, communication skills, motivation to learn more, analytical skills and independence. To the students, independence meant that they were able to take responsibility and ownership of their learning and to manage patients independently.

Based on the six questions given in SS, both WBL cohorts 1 and 2 strongly liked WBL. More than 60% of them reported that WBL enabled them to be self-directed leaners. More than 80% of them felt that it helped them to develop useful optometry skills and knowledge, both technical and soft skills, so as to be work-ready and provided them with an engaging learning experience. Last but not least, more than 70% felt that they were more confident in doing their job as optometrist. These attributes were also observed in the Trad cohort but not as much as compared to the WBL cohorts. SS2 and SS3 are attributes focusing on readiness in workplace which was well-developed in students in the WBL cohorts. Early clinical exposure and more hands-on in the WBL model may have played a role.

From adjunct lecturers’ point of view and final module score (through ALS and FMS)

ALS has shown that the adjunct lecturers have remarkably better impression on WBL cohort 1 (mean score of 3.8) as compared to WBL cohort 2 (mean score of 2.9) and Trad cohort (mean score of 3.3). They felt that WBL cohort 1 had exhibited good interpersonal skills, critical thinking skills and traits of an independent optometrist. However, these were not as clearly evident when the cohort size was increased (in WBL cohort 2), which only exhibited reasonably good interpersonal skills but quite poor in the other two attributes namely critical thinking and traits of an independent optometrist, even poorer than the Trad cohort. This clearly showed that WBL model worked well for one cohort (the smaller cohort) but not the other (the larger cohort).

Based on the academic performance (with FMS as an indicator), WBL model produced variable outcomes in the four core optometry modules studied, and WBL cohorts 1 and 2 performed differently (Figures 2 & 3). It was clear that WBL model worked well for practical oriented modules like CP3062 and CP3066. On the other hand, it had no impact on CP3065 and CP3056 which were theory-oriented modules. The different FMS in WBL cohorts 1 and 2 in CP3056 indicated that the two cohorts performed differently although both cohorts went through the same teaching approach.

In our current version of WBL, content of the four core modules were delivered using flipped learning followed by in-class activities/case-discussions; and students learned hands-on optometric examination skills through clinical training by following patients from each of the major clinical disciplines and across different venues of care over a substantial period of time at SPOC. During clinical training, skills and knowledge of the above mentioned four modules were integrated, and students learned to apply theory and knowledge into practice. Alongside this, it also provided learners with the opportunity to gain their generic employability skills.

REFLECTION ON THE WBL MODEL AND AREAS FOR IMPROVEMENT

We have gained valuable insights from our experience with the 2 WBL cohorts. The feedback from the students and adjunct lecturers provided us with 2 different and independent perspectives in our endeavor for continual improvement of the model (CDIO Standard 12). Our WBL adoption may not be perfect but this paper showed that there are positive aspects and also identified several areas for improvements that need to be addressed.

Advantages: experiential learning with early exposure to real-life patients with lots of hands-on experience in a fully-equipped learning space, the SPOC. The integrated curriculum is designed to develop good technical skills and the professional dispositions essential for a practising optometrist.

Assessment*:* a mix of formative and summative assessments was favoured by students in this study. Students preferred cumulative assessment over the entire semester, instead of one major heavy weightage summative assessment. This form of continual assessment helps students to gradually enhance their learning. The assessments have to be designed to integrate teaching content and the hands-on components.

Facilitation: students take on an active role since most activities of learning are student-led and faculty-guided. The role of the lecturer is that of a facilitator and not that of a direct instructor. Both students and lecturers have to be comfortable with this model to have successful and enriching learning experience. In addition to facilitation know-how, lecturers also have to build rapport with the students and be role models for the students to emulate.

Peer learning/peer tutoring*:* students mainly managed their learning by discussing and clarifying with their peers, within their circle of friends. Chou et al. (2011) demonstrated that using peer groups helps in building supportive learning networks and facilitated reflection, and allows students to develop professional dispositions like communication, collaboration and teamwork.

Resources: WBL is a faculty intensive and resource intensive model (Hirsh et al., 2012), planning of details is critical since the learning and assessment needs to be integrated. Students require more personal attention and mentoring from their lecturers who follow through the entire semester with a small group "students-faculty learning communities". It also requires sufficient time for the continuity of care (Bentley, 2015). WBL model hence works better for smaller cohort size particularly in clinical training component. Manpower constraint and a larger student cohort may contribute to poorer students' performance. Moving forward, a "customised" WBL model may be needed for teaching different modules in optometry.

There are multiple benefits of the WBL model as clearly reflected in the learning outcomes for our optometry students, the most important of which is the development of SDL skills. However, training highly competent optometrists with good technical skills and who exhibit good interpersonal skills, critical thinking and good traits of an independent optometrist is a challenging journey.

CONCLUSION

The WBL model was able to develop self-directed learners and produced better academic performance in "practical-oriented" modules, as compared to the students taught the traditional way. WBL helped develop professional dispositions as well as generic employability skills among optometry students, thus enabling them to be work ready. To scale WBL i.e. to adopt WBL for larger cohorts of students and to achieve good learning outcomes, considerations must be given to faculty and resource availability, which it demands.

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FROM LAB-BASED TO HOME-BASED: APPLICATION OF BLENDED LEARNING

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ABSTRACT

Year 2 students from the Diploma in Electronic Systems course in the School of Engineering, Nanyang Polytechnic had to complete a project as part of the Electronic Communication module through blended learning. The project development involved circuit connections, coding and testing to demonstrate the wireless communication between two Arduino boards to solve real-life problems. With all classes converted to home-based learning during the pandemic, this poses a challenge for lecturers to quickly convert hands-on engineering project with hardware and software development online while ensuring that learning outcomes were not compromised. This paper will explain how the learning outcomes were achieved via Tinkercad during the home-based learning period. The paper will also cover the various means allowing learners to integrate both hardware and software to implement a solution for the identified problem statement. Some of the challenges faced along the implementation will also be shared, together with measures put in place to mitigate the challenges moving forward.

KEYWORDS

Home-based learning, Blended learning, Project development, Active learning, Standards: 8

Note – In the context of Nanyang Polytechnic, the term ‘course’ refers to a ‘program’ while the term ‘module’ refers to a ‘course’. For example, *Diploma in Electronic Systems* is a course; *Electronic Communication* is a module.

INTRODUCTION

The learners from the Diploma in Electronic Systems course study the Electronic Communication module in their year 2. The module is designed based on Bigg’s model of Constructive Alignment; where the intended learning outcomes, learning activities and assessments were carefully planned, to optimize learning (Biggs, 2011). The module aims to provide learners with the knowledge of the basic elements of a communication system and how information signals may be transmitted using modulated carrier signals for analog and digital systems.

In order to achieve the learning outcomes, the learners undergo a total of 90 hours in 15 weeks of lecture, tutorial and practical sessions in one semester, with the final aim that learners will develop an understanding of how electronic communication technology could be adopted in modern society through projects. To achieve this final aim, one of the learning activities in this module is the project phase.

Table 1 shows the module's instructional learning outcomes (ILO) for the project portion, with 18 hours for practical and 12 hours for e-learning. The first ILO is rated level 6 for cognitive and level 2 for psychomotor based on Bloom's taxonomy (Bloom et al., 1956), which can be translated to creating and manipulation respectively, where learners are expected to build a system solution with hardware connections and code development for wireless communication. Similarly, based on Bloom's taxonomy, the second ILO is rated level 3 for cognitive, which can be translated to applying acquired knowledge to deliver a project presentation and demonstration.

Table 1. An Excerpt of Module Instructional Outcomes

<table>
<tr><th rowspan="3">Topic</th><th colspan="4">Instructional Learning Outcomes & Hours</th><th colspan="3">Bloom's Taxonomy Domain level</th></tr>
<tr><th>L</th><th>T</th><th>P</th><th>E</th><th rowspan="2">Cognitive</th><th rowspan="2">Psycho-motor</th><th rowspan="2">Affective</th></tr>
<tr><th colspan="4">At the end of this topic, students will be able to</th></tr>
<tr><td>Application Project</td><td>0</td><td>0</td><td>18</td><td>12</td><td></td><td></td><td></td></tr>
<tr><td>Application Project</td><td colspan="4">1. Build a system solution using digital RF transmitter and receiver.
2. Participate in a project presentation and demonstration.</td><td>6
3</td><td>2</td><td></td></tr>
</table>

(L – Lecture T- Tutorial P – Practical E – e-Learning)

This project component is also mapped to the following module learning outcomes:

At the end of this module, learners will be able to:

- analyse analog and digital communication systems by graphical illustrations and applying the concepts in the building of the systems.
- demonstrate the electronic communication concepts through developing and implementing solutions for real-life applications.

As such, the project requires the learners to perform hardware connections and Arduino code development. Learning packages using Storyline were developed to guide the learners, which made it easier for learners to quickly find the information that they need and to implement in bite sizes. After picking up essential skills, learners will propose and implement solutions for real-life problems. We want our learners to embrace Active Learning (CDIO Standard 8),where they will be engaged with self-directed learning to research, identify problems and implement solutions. Hence, learners are free to propose their projects and the complexity of the projects will then be decided by them.

This project forms 20% of the assessment component for this module. Learners are assessed based on their attendance, project features and functionality, contribution, project documentation and question-and-answer. Figure 1 shows the delivery of this project in a typical semester.

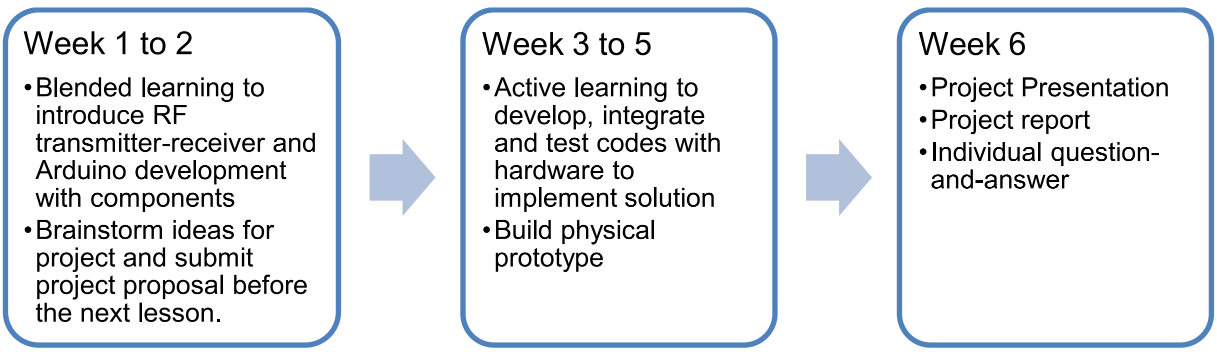

Figure 1. Project Delivery

In this paper, the focus will be on the project phase of the module, explaining how the transition from lab-based to home-based implementation was achieved while ensuring that the learning outcomes were not compromised.

PEDAGOGY

Active learning is a learning method which encourages the learners to be actively or experientially involved in the learning process, and to achieve this, different levels of active learning can be applied, depending on learner involvement (Bonwell et al., 1991). For active learning to take place, learners must be engaged when solving problems, through discussions with facilitators and peers, seeking out knowledge on their own and having a sustained inquiry mindset.

The learning methods discussed can be part of learning activities, that can be used to achieve the desired learning outcomes. In addition, with the aid of technology in education, blended learning approach towards active learning in lessons have been trending and showing improvement in achieving learning goals as well (Dantas et al., 2008, Prince, 2004; Chadia et al., 2019).

PROJECT DESIGN IN THE MODULE

This project involved RF communication between a transmitter Arduino board with sensors and a receiver Arduino board with actuators. Over the course of 6 weeks, learners went from picking up the basic skills in RF communication and Arduino development, wiring sensors and actuators, programming the Arduino boards to read sensor readings, send and receive data and control actuators, to finally implementing their own solution to a real-life problem.

In the following sub-segments, the usual face-to-face lab-based implementation of this project will be discussed first, followed by the home-based implementation.

Face-to-face Lab-Based Implementation

In the first 2 weeks of blended learning, learners went through 4 e-learning packages which covered the theory of RF communication, introduction to Arduino development, circuit connections for transmitter and receiver boards, and sample codes as shown in Figure 2. A challenge was given at the end of each session for them to enhance their codes to meet a certain requirement. They were able to connect sensors such as temperature sensor and light intensity sensor to the transmitter board, read the sensor readings and send data to the receiver board using the VirtualWire Arduino library. At the receiver board, different actions will be performed, depending on the received data to control actuators such as turning on a light emitting diode and rotating a servo motor.

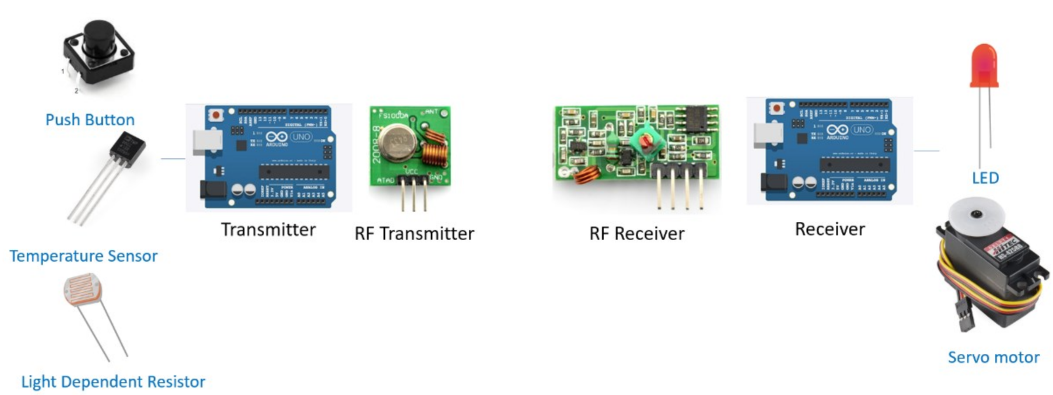

Figure 2. System Overview of the 4 Guided Labs

Armed with the newly acquired knowledge, learners moved on to the next phase of brainstorming to define a problem statement and possible solutions. They worked in pairs and were encouraged to post their ideas in Padlet for others to comment, discuss and improve their ideas. They will then submit a project proposal and the lecturer will give more inputs and suggestions. Project ideas range from smart streetlights, healthcare, doghouse, home security and automation, garden, temperature scanning and access, cafe, carpark to smart trashcan. Please refer to Table 2 for some samples of the project proposals.

Table 2. Project Proposal Submission Samples

Title	Description
Smart Garden	People worry about watering the plants when they are away for long trips. A smart garden with sensors will help to water the plants when soil is dry and turn on the lights when it is dark. This ensures that plants can have enough water and light to grow well.
	Sensors: Soil moisture senor, LDR
	Actuators: Water pump, LED
Smart Study Corner	Outdoor study areas are either equipped with a manually activated fan or air-conditioned. Sometimes, people may forget to turn off before leaving the area which leads to a waste of electricity. A smart study corner with temperature sensor and motion sensor helps to detect people's presence and to turn on the fan when someone is at the area and it is hot.
	Sensors: Temperature sensor, motion sensor
	Actuators: Fan, LED
Remote Patient Monitoring System	In healthcare institutions, it is critical to monitor the vital signs of a patient and nurses must be alert quickly when there is abnormality. This remote patient monitoring system uses heartrate sensor and GSR sensor to monitor the patient. Data will be displayed on the LCD at the nurses' station. Alerts like buzzer and led will be activated, when an abnormality such as fast heart rate or abnormal GSR value occurs.
	Sensors: Heartrate sensor, galvanic skin response sensor
	Actuators: LCD, LED, buzzer

(LED – light emitting diode, LCD – liquid crystal display, LDR – light dependent resistor)

Learners will then spend the next 4 weeks in active learning, to do their own self-directed research in integrating the new sensors and actuators to their transmitter-receiver boards and trouble-shooting their codes and connections, to implement their solutions. Online materials / tutorials were provided to guide them in the correct direction. They will also build a prototype to house all the hardware and to showcase the features.

Learners will be assessed through a sales pitch, where they will present the problem statement and demonstrate the features of their solutions. A project report will also be required to document the project development. The lecturer will conduct an individual question-and-answer session to assess their level of understanding in code development.

Sample Project - Lab-Based Implementation

Figure 3. Learner's Project Submission with Prototype

Figure 3 shows one of the project submissions on smart garden. The learners used soil moisture sensor to monitor the soil moisture level and activate a water pump to water the plants. In addition, a light sensor is used to detect ambient light which will turn on the LEDs if it is dark.

Home-Based Implementation

When Singapore imposed the circuit breaker measures in April 2020 in response to the COVID-19 pandemic, schools were closed, and all lessons were conducted via home-based learning. This poses a challenge for lecturers to quickly convert hands-on engineering project online while ensuring that learning outcomes were not compromised.

Some considerations to take note while researching for a suitable platform include:

- No hardware is given to learners
- Due to the short timeframe of 2 weeks before semester starts, chosen platform should preferably be free-ware and require easy installation by learners or completely online.
- Chosen platform must support multiple Arduino boards in one project, provide a good selection of sensors and actuators, support breadboard connection & code development and simulate results with serial monitor.

A scan of available Arduino simulators reveals that some requires actual Arduino board to upload the codes, some do not support breadboard connections and some only support one Arduino board in one project. After much research and deliberation, Tinkercad platform was chosen for this purpose.

Tinkercad library provides components such as Arduino board, sensors and actuators. Learners were able to go through the entire development process, from placing components on the breadboard, wiring them to the Arduino board, writing codes, running simulation with the ability to adjust sensor readings and printing debugging messages in the serial monitor. Furthermore, lecturers could create a virtual classroom for learners, where all their project development could be viewed and executed by the lecturer. This served as an important channel for the lecturer to view the learners' progress and to give feedback to them.

However, the RF transmitter and receiver modules are not available in the Tinkercad library for wireless communication. For this home-based implementation, the wireless communication is replaced by a pair of wired serial communication between the two Arduino boards and SoftwareSerial Arduino library is used instead of the VirtualWire Arduino library.

Storyline packages were developed with screen recording to demonstrate the features of Tinkercad, Arduino development, circuit connections for transmitter and receiver boards and sample codes. Similar to the lab-based implementation, learners spent the first 2 weeks doing 4 guided lab exercises to get themselves familiar with the Tinkercad platform, building both transmitter and receiver circuits, writing codes and sending or receiving data. In addition, the wireless communication is demonstrated in a video with the actual hardware and the slight differences in codes are highlighted so that learners can appreciate how each project can be easily converted from wired connections to wireless.

During the following 4 weeks, learners brainstormed to identify a problem statement and implement their solutions. The difference from the lab-based learning is that they are limited by the available sensors and actuators in Tinkercad as shown in Figure 4.

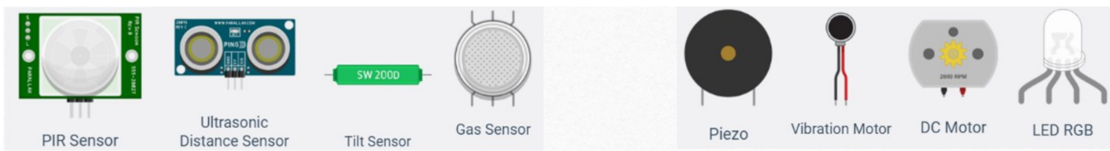

Figure 4. List of Common Sensors and Actuators in Tinkercad

Throughout the home-based learning period, consultations were available through Zoom video conferencing tool. With the virtual classroom, lecturers have direct access to all the projects to view circuit connections and codes, give comments, run simulation and identify errors if learners need help.

Sample Project - Home-Based Implementation

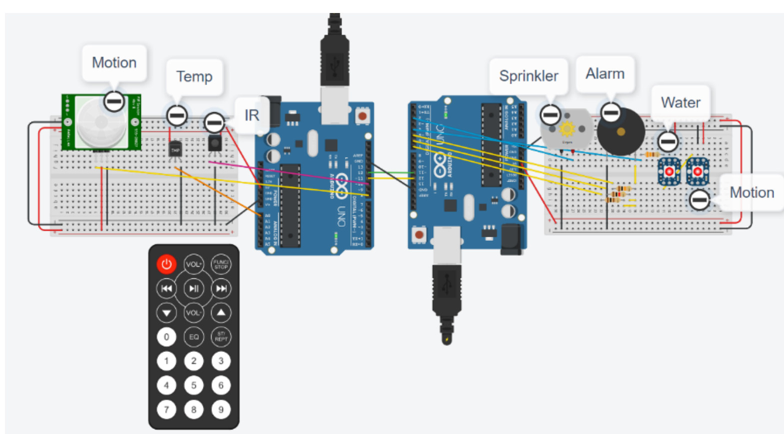

Figure 5. Learner's Project Submission using Tinkercad

Figure 5 shows one of the learner's project submission on smart garden with security alert. The learner used temperature sensor to monitor the temperature and activate a sprinkler (denoted by a DC motor) to water the plants. In addition, a passive infrared sensor is used to detect motion which will trigger an alarm if intruder is detected. This system also comes with an infrared remote controller for the user to remotely arm or disarm the security alert or to control the water sprinkler. Ideally, the learner should have used a soil moisture sensor to detect the moisture in soil and a water pump in place of the DC motor. Due to the availability of the components, an equivalent one was used as a replacement. In terms of the complexity of codes, both are equivalent as they are analog sensors and digital actuators.

Comparison on the Approaches

The comparison between the two approaches can be summarized in Table 3 below.

Table 3. Learning Activities during Lab-based and Home-based Implementations

Week	Activities during Lab-Based implementation	Activities during Home-Based implementation
Week 1 to 2	- Blended learning to cover the following topics: • Introduction to ***RF transmitter-receiver*** and Arduino development ***using hardware and components*** • Wireless switch • Temperature sensor and actuator • Light sensor and actuator - Brainstorm ideas for project and submit project proposal before the next lesson.	- Blended learning to cover the following topics: • Introduction to ***serial communication*** and Arduino development ***using Tinkercad*** • Wireless switch • Temperature sensor and actuator • Light sensor and actuator - Brainstorm ideas for project and submit project proposal before the next lesson.
Week 3 to 5	- Active learning to develop, integrate and test codes *with hardware* to implement solution - Build ***physical*** prototype	- Active learning to develop, integrate and test codes with ***software simulator*** to implement solution
Week 6	- Project Presentation - Project report - Individual question-and-answer	- Project Presentation - Project report - Individual question-and-answer

RESULTS AND DISCUSSION

A total of 17 learners studied this module and completed the project when this study was conducted, using the home-based implementation. A survey was conducted to gather feedback on using Tinkercad platform in terms of achieving the instructional learning outcomes. 14 out of 17 learners responded, and the results is shown in Table 4.

The results from the survey (Table 4) indicated positive experiences from learners, using the Tinkercad platform. Most learners agreed that the Tinkercad platform is easy to use. From the survey responses for Q2, Q3 and Q6, the learners agreed that they have achieved the desired learning outcomes that the instructor has planned to achieve. Other positive comments received mentioned that Tinkercad platform was interesting, fun to use, and that it was good for beginners.

However, there were some shortcomings in the Tinkercad platform too. It was noted that the rating for Q5 was the lowest among all questions asked in the survey. A further review on the learners' comments and concerns found that there were concerns on the limited selection in the Tinkercad library, and hence it imposed a certain constraint in the type of solutions that learners can develop. It was also not a straight-forward process to create a custom component to use in Tinkercad.

Table 4. Survey Results

S/N	Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Q1	Tinkercad platform is easy to use.	57.1%	42.9%	0%	0%	0%
Q2	I learnt about serial communication between the transmitter and receiver.	57.1%	42.9%	0%	0%	0%
Q3	I am able to implement the sensors and actuators that I needed for my project.	57.1%	35.7%	7.1%	0%	0%
Q4	Tinkercad platform allows me to perform the circuit connections and test the codes effectively.	64.3%	35.7%	0%	0%	0%
Q5	Tinkercad platform allows me to develop and implement solutions for real-life applications.	50.0%	35.7%	7.1%	7.1%	0%
Q6	I can demonstrate my project using the Tinkercad platform effectively.	50.0%	50.0%	0%	0%	0%
Q7	Feedback provided by the lecturer is helpful and timely.	64.3%	35.7%	0%	0%	0%

To add on, there was also a lack of security in Tinkercad platform. It was noted that learners enrolled in the same virtual classroom found that they could access each other's work if they knew the nickname used by their classmates. Thus, it will be recommended to the learners that the nicknames used should be personalized and kept for their own usage, to avoid future conflicts.

CONCLUSION

The conversion from lab-based to home-based learning for the project component of the Electronic Communication module was successfully implemented, and learning outcomes were achieved. Learners were able to develop and implement solutions for their identified problem statement despite full-time home-based learning during the pandemic. They were able to go through the entire development process using Tinkercad platform from connecting components on breadboard to writing codes to testing. Some compromises had to be made, such as conversion of wireless RF modules to wired serial connections and to replace certain sensors and actuators with a simple analog or digital input or output.

As revealed by the survey results with the learners, all of them agreed that Tinkercad platform is easy to use and allows them to demonstrate their projects effectively. This provides a convenient platform for them to do a quick prototype of their ideas even though they do not have access to the hardware.

Moving forward, as both lab-based and home-based implementations were able to help learners achieve the learning outcomes and more face-to-face lessons are permitted on campus, a merger of both implementations can be considered. For example, after completing the wireless RF communication between two Arduino boards in campus, learners can be given a task to implement a wired serial communication in Tinkercad. Simulation of certain sensors is also faster in Tinkercad, which can be achieved just by dragging a slider. It can take some time and effort, for example, to raise the temperature from 25^{o}C to 60^{o}C when using an actual temperature sensor. With both implementations in place to complement each other, learners get to use the best of both lab facilities and Tinkercad platform to complete a higher order thinking project.

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CDIO APPROACH ON O2O INTERNATIONAL LEARNING MODEL THROUGH SDG COURSE

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ABSTRACT

This study explores the experiences of an online and on-site (O2O) learning model of the seven international institution courses on Sustainable Development Goals from multidisciplinary fields. The paper explores what makes for effective teaching of sustainability within a multidisciplinary online and on-site context. This experience has impacted social, economic, and environmental sustainability from an engineering perspective. One of the learning outcomes of this course, as stated in CDIO Standard 3.0, is that students had interpersonal learning outcomes that focus on individual cognitive and affective development, such as personal and group interactions, teamwork, and communications in foreign languages. Opportunities are made available for students to study abroad and have international experiences such as internships and exchanges. This course is to practice the actual case studies from global communities in a collaborative manner. The 17 SDGs goals related to Smart Green Synergy were expecting to be understood by students. Member universities and research institutes give the online lecture presentation where students may have global insight into synergy, especially in the engineering implementation, leading to intelligent and green resources to overcome the climate change issue. The pandemic of the COVID-19 situation constrained the five universities in South East Asia to carry out online classes. In contrast, an on-site course was performing by Feng Chia University students with normal class activities. Students are encouraged to think critically to formulate problems, provide a solution internationally and define issues and solutions tailored to SDGs. Students' grade distribution showed a good result of achievement, which implied the expected learning outcomes had been achieved. Result analysis showed that from the 16.67% "Very Good" category in the mid-term, it increased to 42% in the final term. Other classes have decreased, but some are stable. Overall, there was an increase in the study results' improvement by approximately 150%.

KEYWORDS

SDGs, smart green synergy (SGS), CDIO, online and on-site (O2O), international course, Standards: 2, 3

INTRODUCTION

The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by all United Nations Member States in 2015 as a universal call to action to end poverty, protect the planet (Murphy, 2006). The Sustainable Development Goals (SDGs) constitute a working agenda for the international community to ensure a better world for future generations (Zamora-Polo, Sánchez-Martín, Corrales-Serrano, & Espejo-Antúnez, 2019). In response to the growing urgency for sustainable solutions, society's stakeholders increasingly take action against this negative development and contribute and make the planet, economy, and society more sustainable. The SDGs offer an opportunity to extend Education for Sustainable Development (Shiel, Smith, & Cantarello, 2019). Education for Sustainable Development (ESD) was defined as a learning process (or approach to teaching) based on ideals and principles that prepare people of all walks of life to plan for, cope with, and find solutions for issues that threaten the sustainability of our planet (Rieckmann, 2017).

The CDIO Initiative is an innovative educational framework for producing the next generation of engineers, which is introducing in the early 2000s. It adopts 12 standards to provide education guiding principles as guidelines for educational program reform and evaluation, create benchmarks and goals with the world-wide application, and provide a continuous improvement framework. It supports students in acquiring a rich understanding of technical fundamentals while simultaneously developing the necessary professional skills required of a practicing engineer (Malmqvist et al., 2020). The purpose of the CDIO is summarized as having an in-depth understanding of the core technologies and innovating in engineering, and appreciating the broader long-term influence on society (CDIO 2010) (Summers, Corney, & Childs, 2003) The goals of CDIO include educating graduates with a deep and working knowledge of engineering fundamentals, leading in the development and operation of complex technical systems, and who have a strategic understanding of the role and impact of technology in society (Jambari et al., 2018). Providing students with dual-impact learning experiences based on an engineering project's lifecycle, the Conceiving – Designing – Implementing – Operating (CDIO) of real-world products, processes, and systems (Zamora-Polo et al., 2019). CDIO Standards 3.0 that was implemented in 2020is an update of Standards 2.0. The UN goals for sustainable development (Assembly, 2015) challenge engineering programs to broaden the taught goals for engineering, i.e., optimizing technical and economic performance to the simultaneous achievement of economic, environmental, and social sustainability (Malmqvist et al., 2019).

Universities play a crucial role in sustainable development and for adopting the SDG agenda, such as through University Social Responsibility (USR) program to help the community have better knowledge to increase the quality of life. There is no doubt that education is crucial for achieving the SDGs (Vladimirova & Le Blanc, 2016). Although education is directly related to Goal 4, education is transversal to many SDGs (Lee et al., 2016). The promotion and teaching of SDGs at university should consider the global education concept for Sustainable Community Development. Teaching and promoting the SDGs requires developing students' competencies; these competencies must be worked on through strategies and teaching methodologies and must be evaluated. Smart Green Synergy (SGS) is an international course designed by the Feng Chia University in collaboration with five universities in South East Asia and one research council in Europe. The seven Institutes are Institute of Technology Bandung (ITB), Indonesia, Sam Ratulangi University (UNSRAT), Indonesia, Chiang Mai Rajabhat University (CMRU), Thailand, Mae Fah Luang University (MFU), Thailand, Mae Jo University (MJU), Thailand, and National Research Council (CNR), Italy. Eighty students participated in this course, with 45.7%

from ITB, 40.7% from FCU, 4.9% from CMRU, 4.9% from MJU, 2.5%, and 1.2% from Unsrat and MFU, respectively (Figure 1).

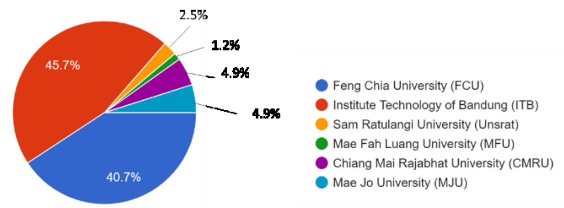


Figure 1. Percentage of students participating in SGS international courses

This study explores an online-to-on-site (O2O) learning model for the new normal via the international course on Sustainable Development Goals. One of this course outcomes is that students had individual and group interactions, teamwork, and communications in foreign languages. Opportunities are made available for students to study abroad and have international experiences such as internships and exchanges. This project aims to bring forward the experiences from the O2O teaching method, by CDIO approach, and to evaluate the students' outcomes through the project. If it is significantly successful in gaining students' targeted outcomes, this project can be an excellent model to disseminate to other educational institutions.

METHODS

The strategy for engineering education known as the CDIO Initiative through the guidelines of CDIO standards 3.0 refers to an international project to emphasize learning through practice by following the stages of Conceive, Design, Implement and Operating that adopting the principle of sustainable product, process, system, and service lifecycle development and deployment. The value of following the CDIO standards has been recognized in secondary and higher education and practitioners extending their knowledge (Summers et al., 2003). Students to be in a position to succeed the CDIO structure should cover technical expertise and reasoning, personal, professional, and lastly be able to implement the CDIO steps in organizations and society (Berggren et al., 2003), interpersonal skills, and a focus on developing a good understanding of the core theory, related technical skills and teamwork (Zarifis, Efthymiou, Demetriou, & Cheng, 2014).

Distance learning in online programs has been gaining popularity, particularly in the past five years. As with face-to-face education or possibly to an even greater extent, there has not been one delivery model with general acceptance and adoption, but some imaginations of what distance education and the technology, processes, and people that deliver it should embody (Loyer et al., 2011) . Blended learning is a mixture of O2O learning. In the literature, blended learning is also known as 'hybrid learning' or the 'flipped classroom' (Bowyer & Chambers, 2017) Blended learning focuses on the students, where knowledge is co-built, created, and shared by both teachers and students. It also emphasizes the pre-class and post-class activities and online interaction (Cheung, Lam, Lau, & Shim, 2010) The blended learning model is "learner-centered" and aims to realize students' in-depth and personalized learning through "pre-class, in-class, after-class" and "online + offline" teaching (Li & Mu, 2019).

The O2O teaching method used in this course is a hybrid method that can be delivered during the COVID-19 pandemic to sustain the students' learning environment in these universities. Students in South East universities could not attend the on-site course at campuses due to the

COVID-19 situation; on the other hand, students from Feng Chia University attend the SDG-SGS course on-site. The course was delivered using Microsoft Teams by the professors from the six universities each week in turns, and the students follow it through online and on-site at the campus. Teaching as transfer of knowledge turns into teaching as guiding and providing conditions for learning and competence acquisition.

A series of topics about renewable energy technology and its environmental and social impacts were first selected in the study to share the professors' experience with the students based on the actual projects from each institution. There were a full 18 weeks, which are 12 weeks of online and offline teaching and sharing project experiences, and the rest of the courses were students' evaluation and site visit, as shown in Table.1. There were a total of 81 students from six universities taking this course. Data for the evaluation method was taken from surveys before and after the class started and ended. Students' outcome result was taken from the mid and final exams.

Table 1. SGS Teaching Schedule

Week	Content	Institution	Online/ On-site
1	Course introduction on UN SDGs and Smart Green Synergy	FCU – Taiwan	Online & On-site
2	Chapter 1: How to introduce green technology into villages	FCU – Taiwan	Online & On-site
3	Chapter 2: Advanced Biogas Technology in a Smart Green Synergy Area	FCU – Taiwan	Online & On-site
4	Chapter 3: Green Synergy in Rural Community	FCU – Taiwan	Online & On-site
5	Visiting green synergy field in Dongshi	FCU Taiwan & CMRU Thailand	Online & On-site
6	Chapter 4: Smart & Green Community Development via Living Laboratory in Campus		
7	Chapter 5: Smart e-Waste Monitoring	MFU-Thailand	Online
8	Chapter 6: Smart Seaweed Cultivation: Design, Implementation, Testing, and Monitoring	ITB – Indonesia	Online
9	SDGs & SGS Mid-term Exam	All Institutions	Online & On-site
10	Chapter 7: Sharing of Smart Green Synergy Planning and Actions	FCU – Taiwan	Online & On-site
11	Chapter 8: Symbiosis Energy in Manado City Indonesia	Unsrat – Indonesia	Online & On-site
12	Chapter 9: Environmental impact of Symnergy Model in Rural Community	Unsrat – Indonesia	Online
13	Chapter 10: Smart Green Campus	MJU – Thailand	Online
14	Chapter 11: Sustainable Islands	CNR – Italy	Online
15	Chapter 12: Social Impact of Smart Green Synergy	FCU – Taiwan	Online & On-site
16	Final presentation (I)	Each Institution	On-site
17	Final presentation (II)	Each Institution	On-site
18	Final report submitting	Each Institution	On-site

SMART GREEN SYNERGY INTERNATIONAL COURSE (SGS)

Course Design

Teaching Smart Green Synergy with sustainability concepts to multidisciplinary students is challenging due to their diverse background and discipline-specific skill set and the interdisciplinary nature of the sustainability issues. The course's overall objective was to make students understand the 17 UN SDGs and practice the international case studies to solve relevant problems by green energy. Based on the CDIO standards 2, to do this, students must at the end of the course be able to:

- Interpret the knowledge of the importance of implementing green energy in the digital era;
- Compare the project-based experience from different countries;
- Defining a problem from the target location;
- Presenting the alternative solutions in group interactions or teamwork.

The Smart Green Synergy course design has shown in Table 2.

Table 2. SGS Course Design

Course No.	xxx	Subject No.	General Education Center	Credit	2
Course name	Sustainable Development Goals – Smart Green Synergy				
Course description	All United Nations Member States in 2015 provides a shared blueprint for peace and prosperity for people and the planet, now and into the future, known as the 2030 Agenda for Sustainable Development. At its heart are the 17 Sustainable Development Goals (SDGs), an urgent call for action by all countries - developed and developing - in a global partnership. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests.				
Correlation between Course and Ability: 1. Memorization; 2. Comprehension; 3. Application; 4. Analysis; 5. Critique; 6. Creation Goals 1. To understand 17 UN SDGs and Smart Green Synergy. 2. To practice international case studies via synergy and sharing.					 Ability A2 X3
Six soft powers (for 1st ability): A. Knowledge Exploration; B. Information Cultivation; C. Communication Skills; D. Value Judgement; E. Pursuit of Joyful Life; F. Civil Practice Competitiveness (for 2nd ability): U. Systematic Thinking; V. Critical Thinking; W. Creativity; X. Collaboration; Y. Self-Management; Z: Complex Problem Solving					

Learning Process

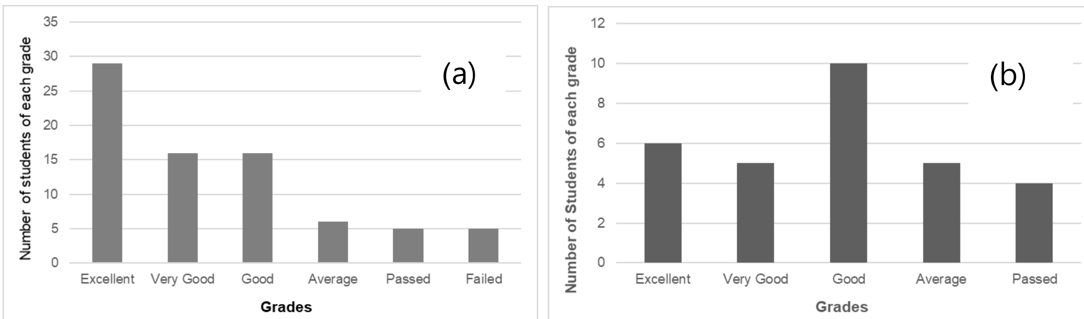
Various learning experience on green energy projects in other countries was arranged for students during this course; including twelve instructional sessions led by different professors from the seven institutions through Microsoft Teams. The lecturers delivered the topics every week, followed by interactive questions and answers from the university students. The first week started with the course introduction by the teachers from Feng Chia University, Taiwan. In the second to fourth weeks, the teacher introduces the green technologies into villages with the Symnergy Model's pilot projects in Manado city, Indonesia (Sinsuw, Wuisang, & Chu, 2020). Students have to learn the knowledge and suitable and affordable technology to the rural community development through this topic, impacting social, economic, and environment. In CDIO model is called the *conceive* stage, wherein this stage is necessary to know the community's needs, affordable, appropriate technology, and implementation strategies. Feng Chia University students have an on-site visit to Dongshi village in weeks five and six to learn the actual condition. At the same time, the students from other universities have joined the activity online. During the on-site visit, students have joined the online lecture from Chiang Mai Rajhabat University, Thailand. Students have to define some problems on-site to provide solutions tailored to green energy. Following the CDIO model, this stage is called the *Design* stage. Students have focused on designing a solution to the addressed need, which contained planning, drawing, and algorithm that describes what could be implemented. In weeks seven to fourteen, the course was conducted by different professors from different universities to share the green energy project-based experience of the global environment to be exposed to a rich set of international affairs. According to the course design, the CDIO model approached on this course can only fulfill the first two stages, Conceive and Design.

The role of teacher-instructors has been identified as highly important for successful group work management and performance. SGS is an interdisciplinary course. Engineering course content combined with social science to learn about social impacts. Teachers using the CDIO 3.0 standard 7, about the integrated learning experiences to create students' activities to stimulate creative and critical thinking consideration of the product planning and design with its responsibility to the social, economic, and environmental impacts. At the end of the course, the students were divided into five groups and used creative thinking to build a feasible concept run on the FCU campus. Using some information and example from other institutions and designed it according to their logical creativity only for 50 minutes. And the further 50 minutes, students have presented their project in a group. This activity has strengthened students' teamwork, capacity building, creativity, initiative, competitive and communication skills. Then, in the final term, students from FCU were divided into ten groups, whereby each group consist of 4 to 6 students. Every group has chosen one project idea that feasible to implement to overcome the climate change issues. Each group present it and choose the best idea, concept, and assumptions to provide the solution, such as drawings, argumentation, explanation, logical reason, and successful project examples as seen in Figure 2.

Figure 2. Group activities: Conceive and Design

Students Evaluation

Student learning is an essential outcome of education and is used to examine the quality of courses. Learning may be classified into two sub-constructs: achievement (actual grades) and perceived learning (self-report of learning). Achievement is generally measured by grades that students have earned in the course activities throughout the course (Rovai, Wighting, Baker, & Grooms, 2009). Evaluation helps to build an educational program, assessing its achievement and improve upon its effectiveness. It also provides valuable feedback on the design and the implementation of the program. There were two times evaluation on the SGS International course. The first evaluation is Mid Term. The midterm evaluation was distributed to all participants from six universities which are 80 students in total, whereby 30 were from Feng Chia University, Taiwan. A set of multiple-choice questions regarding the material course during half-semester was distributed using Google form to the six university students. Students have to answer and submit it within 60 minutes. The score intervals are divided into six classes, namely *Failed* (0-50), *Passed* (51-60), *Average* (61-70), *Good* (71-80), *Very Good* (81-90), and *Excellent* (91-100). Based on the mid-semester evaluation results, 38.75% got excellent results, 21.25% were very good, 20% were good, 10% on average, 8.75% passed, and 6.25% had failed. The evaluation results, particularly for 30 Feng Chia University students who attended the on-site lecture, 20% were excellent, 16.67% were very good, 33.33% good, 16.67% and 13.33% were average and passed, respectively. Students who were not attending the mid-term exam were given another opportunity to take the following week's exam. Figure 3 shows the result of students' achievement in Mid-term evaluation.



(a) Six universities students' grade distribution on Mid-term, (b) Feng Chia University students' grade distribution on Mid-term

Figure 3. Students' achievement on Mid-term exam

The second evaluation is the final semester exams conducted by the respective university. Feng Chia University students are divided into eight groups consisting of three to four students. Each group must define problems related to the predetermined SDGs. Furthermore, each group presented the solution to the problem using designs, pictures, slides, and other creativity using English. It is in the CDIO stages of *conceive* and *design*. Through this grouping system, students are trained to work together on teamwork and more engaging in applying ideas. Active learning in CDIO standard 8 said that small-group suitable method for teachers to get feedback through discussion, debates, and feedback about what students are learning. It can be seen in Figure 4 that the distribution of final semester test scores has increased when compared to the mid-term. The final-term evaluation results showed 42% were Very Good, 33.3% were Good, 13% Excellent, 10.6% were average, 10.43% and 3.67% were passed and failed, respectively.

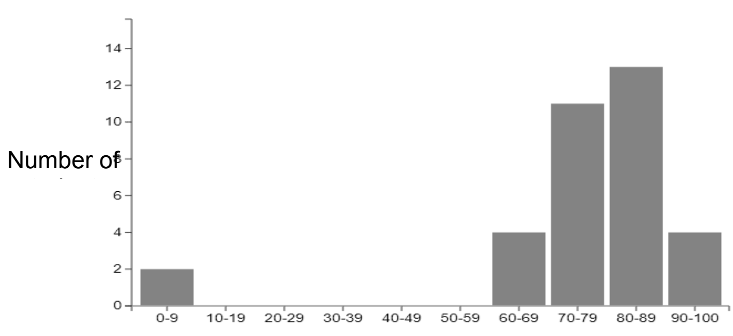


Figure 4. Students' achievement on Final-term exam

Course Enhancement

When this two-credits course was being offered for the first time, the five institutions in Southeast Asia agreed with it enthusiastically. Several insights in light of contents, process, and outcomes were gained for continuous course improvement. The course was set as the first international course among the six universities consortium as a starting point for the future international curriculum. Each university in the consortium adopts this course as one elective course in the curriculum that the students from the undergraduate level may elect as one of the credits. Besides, students who have taken this course have priority as exchange or intern students among the consortium if they meet the faculty's main requirements.

DISCUSSIONS

This paper aimed to explore an online-to-on-site (O2O) learning model of an international course on Sustainable Development Goals. Following the CDIO standards 3.0, students showed solid teamwork in groups on how students define and solve problems based on the sharing experience internationally at the end of the semester. Based on the CDIO 3.0 Optional Standard 4, students taking this course have more opportunities to apply for internships or exchange students.

Students' ability, which was designed in this curriculum, is to achieve the A2 and X3. For A2 ability, students have to understand the knowledge exploration. With the knowledge exploration, students can cultivate interest in learning in multiple fields, integrate knowledge across domains, and continue to engage in cross-field learning. The X3 ability expects students to collaborate. With collaboration, students will have the ability to respect differences, emphasize complementarity, adequate division of labor, integrate expertise from different backgrounds, and complete projects that individuals cannot overcome

Based on the mid-semester student evaluation results and the distribution of scores shown in the bar chart above, the results achieved tend to be high in general. From the 16.67% "Very Good" category in the mid-term, up to 42% in the final term. There are other categories that have decreased but some are stable. From the results of the analysis, there was an increase in the improvement of the study results by approximately 150%. Thus, the teaching approaches and methods used in this course are following the expected outcome. Although there are still students who fail, the percentage is deficient. Several factors influence student failures, such as withdrawing or dropping courses, not attending lectures, or other conditions that hinder the classes. The results achieved by Feng Chia University students who took on-site courses, the distribution of scores tended to be in the middle. The majority of students get "good" grades. It is not too high. This condition shows a pattern that students who take on-site lectures tend to attend classes regularly because other factors influence it, such as meeting college friends and lecturers directly to discuss or ask questions to get a clearer understanding. However, the lack of mastery of foreign languages such as English, which is the language of instruction for the international course, could be one reason for the achievement of FCU students' scores who are not many in an excellent position.

CONCLUSIONS

This study has explored the CDIO implementation to the s.School course at Feng Chia University. Bloom's taxonomy divides learning into three potentially overlapping domains; one of them is the cognitive domain which includes six different classification levels: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation (Bloom, 1956) Based on Bloom's taxonomy, this course design only reaches the second level, Knowledge and Comprehension, because it is generally offered for all undergraduate students, from first-year students to senior students. This course aims to give a deep understanding of UN SDGs to the students, and later students will know how to implement it in their fields.

The CDIO standards 3.0 approach of learning outcome on personal and interpersonal in this study has good result as can be seen from the students' achievement by grade distribution of the exams. Individual achievement results can be seen through the mid-semester exam. The results of group work achievement and the percentage of the ability to define problems and provide solutions are seen in the final semester exams' results. The increase in student learning outcomes can be seen clearly from the above bar chart. Through the improvement of learning achievement, it can be implied that the CDIO approach is suitable for online to on-site international courses. Thus it can be concluded that the CDIO approach was successful in the SDG-SGS course with the expected outcome.

For future perspectives, the CDIO method is suitable for online, on-site, and blended learning lectures. This method can be applied for engineering study by considering social, economic, and environmental sustainability. This is in line with UNESCO's programs, Education Sustainable Development, which empowers learners to take responsible actions for environmental integrity, economic viability, and society. It is about lifelong learning and is an integral part of quality education which addresses learning content and outcomes, pedagogy, and the learning environment. It is sustainability education that empowers students to create positive change for our evolving world.

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A NEW APPROACH TO ENGINEERING EDUCATION AT TSURUOKA KOSEN

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ABSTRACT

As a new approach in the Integral Engineering Class (IEC) at Tsuruoka KOSEN (National Institute of Technology Japan), a joint PBL class of the second- and the fourth-year students was conducted, and the fourth-year students acted as facilitators in their group discussions. Fourth-year students are intended to support the second years' discussions by supplementing their knowledge and experience, leading to deeper second-year student discussions. Furthermore, experience in teambuilding and leadership are expected to lead to the development of initiative in fourth-year students. The effects of the joint class were investigated using a questionnaire survey on self- and mutual evaluation. A preliminary analysis of the questionnaire results suggests certain positive effects from the group discussion process, such as active discussion, diversity of opinions, and summarized group opinions. We intend to continue improving the IEC based on the questionnaire results.

KEYWORDS

KOSEN, Integral Engineering Class (IEC), Active learning, PBL, Leadership, Standards: 3, 7, 8.

INTRODUCTION

Tsuruoka KOSEN (National Institute of Technology Japan) considers the following competencies to be essential for high performing engineers who can successfully contribute to solving real-world problems: (1) creativity: the ability to discover and solve practical issues; (2) initiative: presentation skills and their expressiveness; (3) team-building skills: cooperation/collaboration and leadership; (4) communication skills: active listening, dialogue and discussion. These abilities correspond to CDIO syllabus 2: Personal and Professional Skills and 3: Interpersonal Skills. To this end, Tsuruoka KOSEN instituted a new "Integral Engineering Class (IEC)" for first-year students to fourth-year students. It is based on active learning and designed to develop the skills needed for engineers. In the IEC, students learn about engineering ethics, intellectual property, entrepreneurship, and career plans. In addition, a wide variety of project-based learning (PBL) group work is introduced for each year to develop creativity, team-building skills, and communication skills.

The main purpose of the curriculum is to instill "generic skills," such as initiative, communication, and teamwork, over the four years that students are in the program by using active learning in the classroom. The integral engineering curriculum is delivered through lectures and project-based learning (PBL) classes where teams work together. Lectures are on engineering ethics, intellectual property, entrepreneurship, and career plans so that students acquire the basic knowledge necessary for working as an engineer. For example, engineering practitioners are invited to give lectures with the goal of delivering technical knowledge and cultivating an engineering mindset in the students. After the lecture, small groups discuss the lecture contents in order to cultivate their understanding and thinking skills by discussing themes and summarizing their ideas.

In each of the four years of the program, PBL is used intensively to cover various themes. Group work helps students to learn about team building, and to comprehensively develop their abilities for finding and presenting solutions. A further goal of group work is to foster initiative and communication. The generic skills being fostered in PBL are required in the real world and can be attained through active learning. See Figure 1 for a flowchart of how PBL framework relates to real world skills.

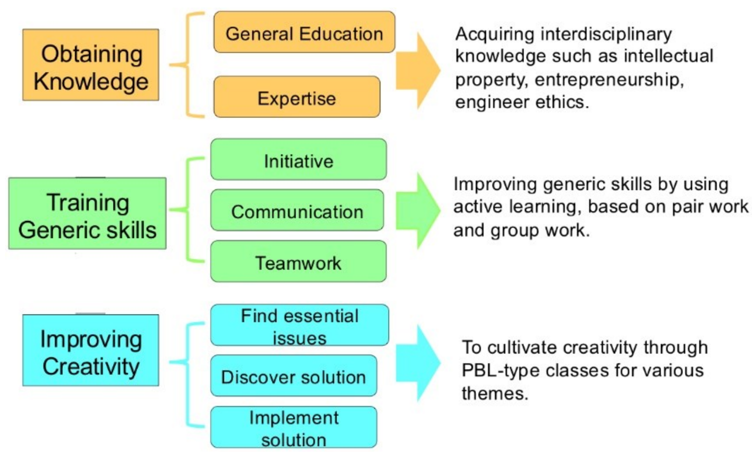


Figure 1. Framework for integral engineering curriculum

METHODS

One of them, there is a joint PBL class for second- and fourth-year students, in which the fourth-year students are the facilitators for the second-year students' group discussion. The fourth-year students can support the second-year students by supplementing their knowledge and experience, and this can allow for second-year students to engage in deeper discussion. In addition, the experience of team building, and leadership can lead to the development of initiative among fourth-year students.

Group work that mixes different years has been introduced in other KOSENs (engineering colleges) and universities (Hiraishi *et al.*, 2017; Uchida *et al.*, 2017), but the unique characteristic of our approach is that second-year students are encouraged to generate ideas. Fourth-year students specialize in facilitating and consulting group work, drawing out second-years' ideas, and helping them to summarize those ideas. By setting up the fourth-year students' role in this way, it is expected that they understand the work of improving the quality of the teams' outputs which contributes to leadership education.

In the current study, a group of eight students consisting of four second-year students and four fourth-year students were the participants. The theme of the group work was sustainable development goals (SDGs) (United Nations, 2015). The second-years attended a lecture on SDGs and related global environmental issues prior to the group work. The fourth-years had attended the same lecture two years prior, and they participated in the group work on the premise that they had knowledge of the lecture content on SDGs. The group was presented with a problem to be solved, and the students were required to present their solution. We verified the effects of this approach by administering a questionnaire survey to each of the second- and fourth-year students.

Table 1. Questions

Ⅰ	Did you share the theme in your team?
Ⅱ	How was the team atmosphere?
Ⅲ	How active was your team?
Ⅳ	Did you gather diverse opinions?
Ⅴ	Were the team's ideas summarized?
Ⅵ	Did your facilitators (or second-year students) employ active listening?
Ⅶ	How many questions did your team ask each other?
Ⅷ	Could your facilitators (or second-year students) organize ideas well?
Ⅸ	How easy was it to understand the facilitation?
Ⅹ	Did the facilitator hold a neutral position?

RESULTS AND DISCUSSION

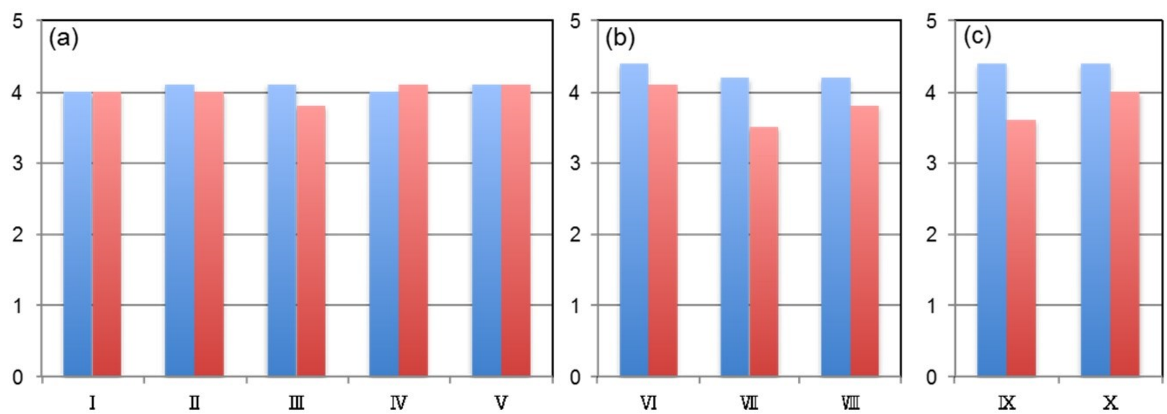
The questionnaire was comprised of 10 questions: group work in general (Ⅰ to Ⅴ), mutual evaluation (Ⅵ to Ⅷ), and the facilitator (Ⅸ to Ⅹ). Answers were on a 5-point Likert scale (not good: 1 to good: 5). Questionnaire results are shown as the average score for second-years and fourth-years respectively for each question. The results are shown in Figure 2.

The first part of the questionnaire about group work in general shows that both the second-year students and fourth-year students gave average high scores of 4 points or over. In other words, both groups of students experienced a high level of satisfaction with the process and output of the group work, demonstrating that this approach was effective. See Figure 2a for a histogram showing the results.

The second part of the questionnaire was on mutual evaluation comprising active listening, asking questions, and organizing ideas. The results showed that second-year students evaluated fourth-year students very highly, with an average of 4.2 points or more. On the other hand, the fourth-year students evaluated the second-year students with low average scores of 3.5 on the number of questions asked. This suggests that the second-year students did not demonstrate enough initiative from the perspective of the fourth-year students. See Figure 2b for a histogram showing the results.

The third part of the questionnaire concerned facilitators, and second-year students' evaluations of fourth-year students were very high. In other words, it was suggested that the support of the fourth-year students for the second-year students was very effective when undertaking group work. On the other hand, the fourth-year students scored the facilitations lower, indicating that they did not believe that the second-year students were easy to work with. See Figure 2c for a histogram of the results. The fourth-year students had received training on facilitation in advance of the group work, but it is thought that more extended training may be necessary.

The fourth-year students generally gave lower scores than the second-year students, but this is probably due to the Dunning–Kruger effect (Kruger, J., & Dunning, D. 1999). That is, it can be inferred that there is a difference between the level considered necessary by the second-year students and the level considered necessary by the fourth-year students. However, overall, there are similar tendencies demonstrated by the scores given by both second- and fourth-year students, and it is considered that the group work process and outputs were effective. In the future, as a way of verifying the effect of these initiatives, we are considering more objective verification by conducting the PROG test (Kawasaki *et al*., 2020).



	□	□	□	□	□	□	□	□	□	□
2nd year students	4.0	4.1	4.1	4.0	4.1	4.4	4.2	4.2	4.4	4.4
4th year students	4.0	4.0	3.8	4.1	4.1	4.1	3.5	3.8	3.6	4.0

Figure 2. Results of questionnaires. Blue: second-year students; red: fourth-year students

CONCLUSIONS

As part of the IEC, we conducted a joint PBL class in which fourth-year students acted as facilitators for the second-year students' group work and verified the effectiveness of that approach. Each group on the theme of SDGs consisted of four second-year students and four fourth-year students in the same course. As facilitators, the fourth-year students specialized in consulting of the group work. The second-year students concentrated on coming up with ideas. The purpose was to verify how they would affect the promotion of group work by clarifying the role. After the work, questionnaires were conducted for each of the second-year students and fourth-year students to verify whether the group work proceeded smoothly or not. From the questionnaire results, especially in areas concerning group work process and output, the scores that both groups gave were high, and positive effects of this class were seen. On the other hand, weaknesses such as a lack of initiative on the part of second-year students and lack of facilitation skills in fourth-year students were also seen. We will feed these results back and use them for improvements to the IEC.

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IMPLEMENTATION OF E-PRACTICAL LESSONS DURING PANDEMIC

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ABSTRACT

The education sector was not sparred from the impact of COVID-19 and was forcefully made to adapt to the rapid changes arising from virus situations in various countries as necessary measures were implemented to prevent the virus surge and protect life. In the mist of the pandemic, learning should not be stopped even though lock-down and restrictive measures were placed. In the context of engineering education, lab practical sessions are paramount to the learning of the students where practical hands-on provide the students with the necessary experiences to complement their theoretical studies. With several schools been closed and switching to remote online education, the impact of lab practical studies was major as students were no longer able to return to school to use their equipment for learning and to perform their lab experiment. Through the exploitation of technologies, School of EEE (Singapore Polytechnic) addressed the challenges of e-practical disruptions which Singapore students faced during the “Circuit Breaker'' (CB) period in an innovative approach. During the CB, e-practical videos were produced for modules where learning were directly affected due to closure of labs as students were not allow to return to school to carry out day-to-day learning. The lab videos were designed to be short to enable micro-learning, allowing the students to better focus on the bite-sized content while enabling one to study individually at home through a flipped approach. Attributing to the joint effort and hard work from both teaching and technical staff in the video creation and editing process, the school was able to deploy e-practical videos to students weekly since the start of the “Circuit Breaker”. Till to date, more than 450 labs videos were created and deployed across different modules. With SP transition into “safe re-opening'' as virus situation in Singapore gets better, the lab videos were further improved and now jointly utilised as part of the students’ learning complementing other module materials. During the CB, a survey was carried out for more than 300 students who utilised the lab videos and results showed that more than 80% of the students found the lab videos to be useful in their learning and aided them in understanding the topic better while they carried out their full HBL.

KEYWORDS

Flipped learning, Micro-learning, E-practical videos, Standards: 8, 9, 10

INTRODUCTION

The management of disruption due to physical learning environment constraint in the 21st century is now more flexible due to technology advancement and wide adoption of the Internet across the Globe. Unlike the early days where lesson can only be conducted and confined within a physical environment, there are now online platforms and tools available for educators to explore, utilise and customizing them to best suit to the learning of the targeted students. This enable one to be able to do remote studying easily, accessing their learning content anytime and anywhere through the Internet.

COVID-19 is an unprecedented event of this decade that causes major shocks and disruptions to almost all walks of life around the world. It changes the norm of how countries, businesses and individuals carry out their daily routines and interactions with one another. Prior to this worldwide pandemic (WHO, 2020), the industry landscape around the world was already facing pressure from abrupt disruptions due to waves of emerging technologies (Gartner, 2019) and digitalisation of industry, business and education (Agnes, 2012), (Martin & Ertzberger, 2013). COVID-19 rapidly hastened the original timeline for the world's preparation and pushed all into the acceptance of digitalisation for continuity and survivability of businesses. The education sector was not spared from the impact of this virus. In order to "Flatten the curve" and to slow down the speed of virus transmissions, several countries around the world adopted "lock downs" and restrictive orders to limit the flow of human traffic. During this period, many schools around the world were closed or made to carry out their lessons online to prevent mass gatherings of students. In the context of Singapore, we entered the "Circuit Breaker" period on 7 April 2020 (MOM, 2020). All schools and institutes of higher learning were mandated to shift to full HBL. Private educational institutions were similarly directed to do full home-based learning (HBL), or temporarily suspend classes.

As educators in a public Engineering school (School of Electrical & Electronic Engineering, Singapore Polytechnic), we have the duty to uphold the standard of learning and have a critical role to play in ensuring the continuity of students' learning regardless of changes in environment. Practical lab sessions are crucial in training future technicians and engineers. They equip students with the basic competencies to carry out the "hands-on" tasks required of a technical professional. For an engineering school, learning is predominantly carried out in a lab environment. This is where students learn about basic engineering skills, usage of equipment and developing skills in troubleshooting and using measuring tools. It is therefore essential that address the challenge for full home based learning during restriction and come up with alternative solutions to overcome the limits of students being removed from their physical learning environments. In this paper, the School of EEE's collective approach towards the generation of e-practical videos and their implementation during the "Circuit Breaker" to address the needs of the students will be presented. The generated online content was kept short and focused to achieve micro-learning through "Bite-sized" and delivered through a flipped approach. In order to validate the usefulness of the practical videos towards their learning, the analysis from more than 300 students is included in this manuscript. The survey presents a good overview in understanding the students' perceptions on the usefulness of the videos and areas for future improvements.

The rest of the paper is organized as follows: It begins with a discussion on the collective approach to implementing the e-practical videos. Following that, the paper focuses on the use of a micro-learning approach and discusses the categorization of e-practical videos and staff competency needed to support such an approach. The students' survey results and findings are presented in the next section, followed by the comments and feedback from the technical executives (TE) who contributed greatly in allowing this work to happen. Next, the reflection and future works for the development of the e-practical video was presented. Lastly, the conclusion of the manuscript was provided in the last section.

APPROACH TAKEN BY EEE TO ADDRESS LAB REQUIREMENTS

Lab practical sessions are paramount to the students' learning in an engineering school. Quoted from Henry Petroski (Professor of Civil Engineering at Duke University and recognized expert in failure analysis) ***"Science is about knowing, engineering is about doing."*** and Steve Jobs "*Design is not just what it looks like and feels like. Design is how it works*." From an engineering perspective, these quotes highlighted the importance of not relying on just textbook learning. A good future engineer needs to be able to apply, create, troubleshoot and ultimately make things work. Due to the limitations imposed on mass gatherings and movement countrywide during the CB, students were not allowed to return to their laboratories for learning. The School of EEE explored alternative solutions, taking full advantage of our built up competencies in student online learning (Wan, 2019), (Chew et al, 2019), CDIO implementation (Chong et al, 2010), self-directed learning (Toh et al, 2020) and lab competencies of staff, developed within the school over the years. These were put to good use during this challenging period, enabling the school to minimize the learning disruptions faced by students. E-practical videos suited for micro-learning were created, edited and sent out to students. This provided a distinct advantage to students as the content was customized according to the needs of individual module across the different levels and diplomas. In addition, the videos could be integrated with other flipped learning content such as tutorial quizzes and lectures to provide an active learning and holistic experience for the students while they performed self-directed learning at home.

IMPLEMENTATION OF E-PRACTICAL IN EEE, A COLLECTIVE APPROACH

During the "Circuit Breaker" period, there were physical restrictions set in place to limit the number of essential staff returning to the school each day to carry out the implementation of HBL. Teamwork was especially vital during this critical time and the school came together as a cohesive unit to support each other. The technical executives (TEs) from TSA and academic staff (Specialists) worked closely together to construct the video content suited for the module topics. The TEs from the School of EEE also provided additional support by editing and disseminating the videos. Our staff members demonstrated strong teamwork and assisted others who were not able to return to the school.

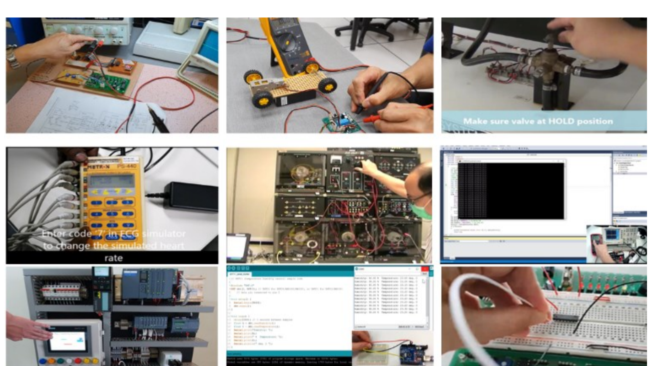


Figure 1. Screenshots from e-practical videos of different modules

The e-practical videos shown in Figure 1 aims to familiarize the students with the individual experiment. They include recorded procedures for lab setup, steps on utilisation of the individual equipment and carrying out the experiment process. In a restricted environment where the student does not have access to the physical equipment, the e-practical videos provided them with a viable alternative to learn about the practical aspects of their module. In the next section, this paper looks into the characteristics of the e-practical video and how the concept of micro-learning was adapted to improve the learning of students.

MICRO-LEARNING AND CATEGORISATION OF VIDEO

Online Learning has been picking up speed and popularity in the last decade due to the easily available learning platforms through MOOC (Massive Open Online Courses) (Hayes, 2016) such as Coursera and edX. However, although most MOOC providers have reported large numbers of registered users for their courses on their respective platforms, the actual number of learners completing the courses was disappointing. Statistics (Forbes, 2019) from edX by MIT show the actual completion rate fell from 6% in 2014/15 to 3.13% in 2017/18. In the adaption of full online learning for all our students in the context of Singapore Polytechnic, we have to ask ourselves these tough questions. Are the students truly gaining real knowledge from the online lessons? Are the students just merely making their presence felt online without learning? How can we uphold our academic rigour and adjust our online leaning content to ensure that the students will be able to achieve good learning outcomes during the "Circuit Breaker"? Micro-learning (Hug, 2015), (Lindner, 2017) could be one of the small steps we take as we grapple with these questions.

"Micro-learning deals with relatively smaller learning units and short term-focused activities" (Hug, 2015). It is commonly associated with the domain of e-learning (Bruck, Motiwalla, & Foerster, 2012). During the "Circuit Breaker" period in Singapore, all public higher learning institutions were mandated to shift to full HBL We adapted the use of Micro-learning to target two key aspects in both the content development of the online material and the learning behaviour of a student. For content development, the e-practical videos were intentionally created to be "bite" sized to enable individual learners to focus on a specific learning outcome. In the School of EEE, we categorized our e-practical videos into three different levels. They were based on the depth of learning in comparison to the physical hands-on lesson and we align them in comparisons to relevant categories of the Bloom's Taxonomy.

The e-practical videos were created with the intention for students to be able to gain familiarities and insights to best achieve the learning objectives for individual lab. Figure 2 provided the categorization of the different depths of learning a student can experience when using the online learning content. During the CB period, the videos deployed for students' usage were at least of level 1 quality. The categorization of the e-practical video is provided next. For level 1, the content aims to provide a visual walkthrough of the physical lab activities to familiarize and prepare the students for their physical "hands-on" session when they eventually return to school. Level 2 practical videos deal with a higher order of learning based on Bloom's Taxonomy that supersedes the objective of getting the student to only be familiar with the experiment. In this level, the video ventures deeper into their learning, enabling them to make connections to theory and allowing them to be able to analyse and evaluate their experiment data. Level 3 aims to emulate the experience in physical labs through 'virtual" hands-on sessions, giving the students a sense of immersion.

Level 1

Understanding and familiarity

Visual walkthrough of the physical lab and seeks to familiarize and prepare the students for their physical "hands-on" session.

Blooms Taxonomy relevant categories:

Remember and understand

E.g. Lab video demonstrating the connection of circuits/system, with narration limited to physical set up and connection description

Level 2

Analysis and troubleshooting

In this level, the video dives deeper into student's learning superseding the objective of been familiar with the experiment. The video should enable the student to make connections to theory and allowing them to be able to evaluate their own experiment data.

Blooms Taxonomy relevant categories:

Remember, understand, analyze and evaluate

Eg. Lab video with narration demonstrating the connection of circuits/system Explanation of learning objectives, troubleshooting techniques are provided. Expected results from experiment is clearly explained.

Level 3

Immersion

The use of Augmented Reality or Virtual Reality to immerse the learner in a simulation of the actual learning environment.

Blooms Taxonomy relevant categories:

Remember, understand, analyze, evaluate and apply

E.g. The use of Augmented Reality or Virtual Reality technology to provide immersive student learning for lab.

Figure 2. Categorization of E-practical videos

Moving beyond the CB period, more e-practical videos are created and added to the video repository. Looking back before the pandemic where only a handful of e-practical videos were created and scope which were limited to individual module, till to date where more than 450 video content were deployed for student's utilisation widespread across modules as they progressively return back to the classroom with improving COVID-19 situation in Singapore. The created e-practical videos are now used in conjunction with their physical lab lesson to supplement their learning and also served as a learning content for their pre-lesson studies before coming into the physical lab. The school will progressively increase the levels of the created videos as we seek to explore the use of AR/VR (level 3) or other simulation tools to provide realistic "hands-on" experiences thus further enhancing the learning experiences of students while carrying out the experiment at home or through a remote site.

SYNERGY OF TE COMPETENCY TO E-PRACTICAL VIDEOS CREATION

In order for technical executives to be able to create the e-practical videos together with the module specialists, they require good foundational knowledge in their respective lab modules and individual experiments. By knowing their lab content well, the critical information from the experiment can be preserved throughout the process of recording, editing and presenting to the students for their learning. The School of EEE established the module competency framework (recently revised in 2019) as a systematic way to define the competency levels of individual TEs for different modules under their care. The definitions for the different levels are shown in Figure 3.

A total of 41 TEs in the School of EEE achieved 100% "Basic" competency for at least one module. 98% achieved intermediate and 40% have progressed to the "Advanced" level. The creation of the e-practical videos was thus undertaken by the TEs based on their competency levels according to the established framework.

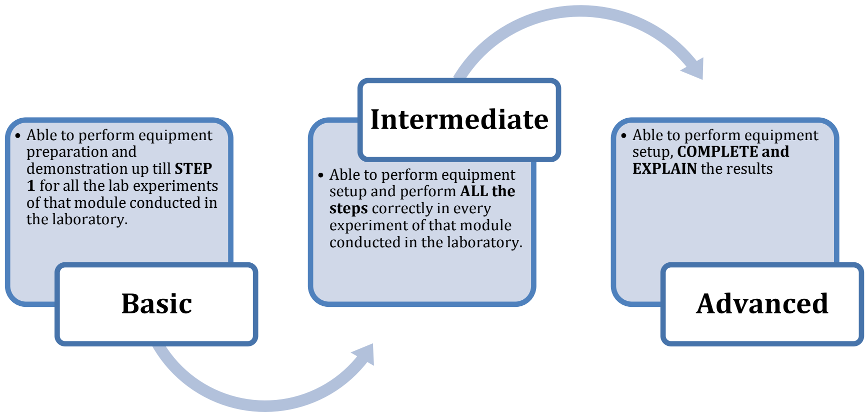


Figure 3. Competency levels for TE in support of modules in the School of EEE

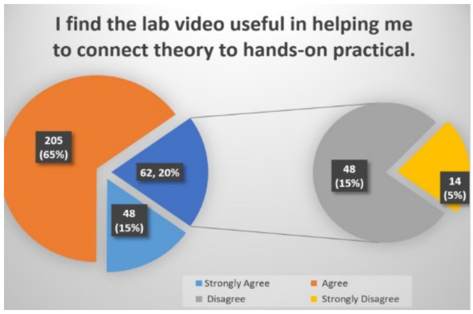
DEPLOYMENT OF E-PRACTICAL VIDEOS DURING COVID-19

During the CB, most of the module practical sessions were affected as students were mandated to perform full home-based learning. The lab videos were deployed weekly to the students in order to minimize the impact to their learning. An advantage of the e-practical videos is in their flexibility of utilisation, as they can be used even after CB. During the catch-up week for labs, students make use of the videos to refresh their memories before returning to school for the actual physical experiments.

The successful deployment of the e-practical videos opens up many opportunities for both manpower and resource optimization for the school. As students gradually returned to school during Post-CB, lab practical session were redesigned to be compressed (2 lab sessions combined into a single one) to maximize the students' learning while adhering to the safe distancing measures. The lab videos enable optimization of student learning, enabling them to familiarize themselves with the procedural steps of practical lab. With the improvement in quality of the lab videos and with more lab videos being utilized for self-learning, lab time previously used for procedural explanation can now be free up for actual practice by both full and part-time students to better build their technical know-how.

STUDENT SURVEY RESULTS

The main objective of the e-practical video is to minimise the disruption in student learning towards practical lab session during the pandemic. It is important for us to be able to know if the videos are useful for them and what are the areas for improvement to better aid their understanding while they are learning from home. For data collection, we have conducted two surveys looking into (1) Effectiveness of using the e-practical videos for students' learning and (2) Mind-set of the TSA staff contributing to the creation of the lab videos. For the student survey, 317 students from year one to three participated. Each question in the survey was measured using the 4-point Likert Scale format (Strongly Disagree, Disagree, Agree and Strongly Agree) with open-ended questions at the end.



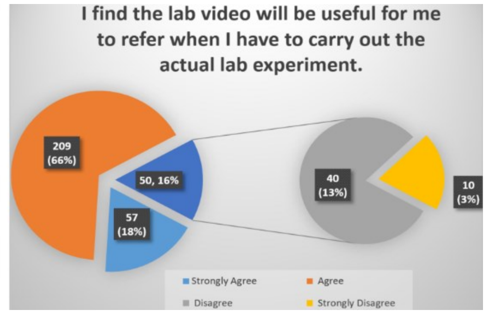
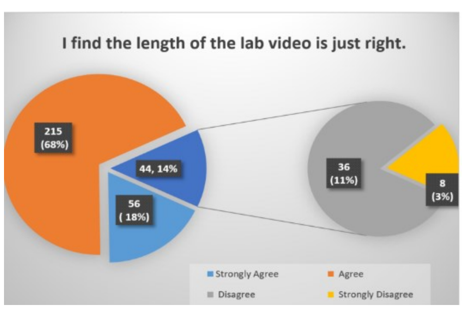


Figure 4a. Connect theory to hands-on practical Figure 4b. Familiarity to actual lab experiment

Figures 4a and 4b focused on the usefulness of the e-practical videos during their dissemination to the different years of students in the School of EEE. Figure 4a shows that out of the 315 students who answered the question, 80% (253 students - Strongly agree and Agree) found the videos to be useful in helping them apply the theoretical knowledge they gained from lectures and tutorial. The connection between theoretical learning and practical is an important aspect of learning especially in an engineering context where theoretical knowledge gained will not be sufficient if the students want to find solutions to solve real-world problems. Figure 4b surveyed the students' feedback on the usefulness of videos as a reference when doing the actual lab. The data showed that out of the 316 students who answered this question, 84% (266 students - Strongly agree and Agree) responded positively. This aligns with our original objective of the e-practical videos to improve the familiarity of the students in practical aspects and allow them to improve their learning experience.



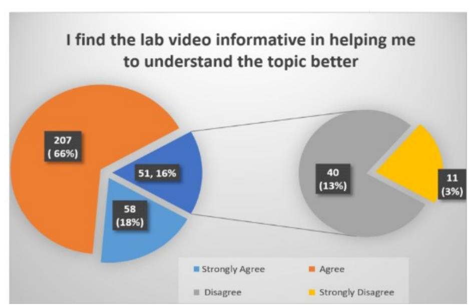


Figure 5a. Aspect of Micro-learning Figure 5b. Understanding of topic

Figures 5a and 5b focused on the characteristic of the e-practical videos and whether the presentation of information is useful in helping the students understand the topic better. Figure 5a shows that out of 315 responses, 86% (271 students - Strongly agree and Agree) thought that the length of the videos were just right. During the creation of the e-practical videos, the length of the videos were kept intentionally short to enable "bite sized" learning. The students will now have the flexibility to hone in on the areas they need help with, and to watch and review that specific topic again anytime they wish. Figure 5b demonstrated this fact and shows that out of the 316 students who responded to the question, 84% (265 students - Strongly agree and Agree) felt that the videos are informative and helped them to understand the topic better. However, Figure 5b does reveal that 16% (51 students - Strongly disagree and disagree) felt there could be improvements. This could be addressed in the future as more Level 2 and 3 videos are created. Through virtual "hands-on" and improvement in the details of the videos, better knowledge transfer and learning efficiency could be achieved.

In the next section, feedback of students were consolidated and presented. The open-ended questions enabled us to gain better insights into the students' learning behaviour and usefulness of the e-practical videos.

Findings from responses collected from three open-ended questions

Question 1: What do you like about the lab videos?
Question 2: What do you dislike about the lab videos?
Question 3: What could have been done better for any one of these three - Lab video, online learning material and online assessment - to help you in your learning during full HBL?

For open-ended question 1, the students generally agree that the e-practical videos are informative and enabled them to visualise and prepare for the physical lab when they return to school. The repetitive nature of the e-practical videos is useful for some students as they were able to review parts of the e-practical concepts they were not familiar with at their own time and pace. Some of the comments from students were as follows:

"I liked how the tutor demonstrated the lab experiments so that we know how to carry out the experiments ourselves. Also, I can rewind the videos if I need to clarify something without asking the teacher to repeat themselves."

DCPE year 1, Anonymous

"They help to guide us through lessons even though we are not in campus."

DEEE year 1, Anonymous

"It is very step-by-step in the procedures. Hence it is okay for students to follow through".

DEB year 2, Anonymous

"They can serve as a good reference when I have problems carrying out the actual experiments".

DEEE year 3, Anonymous

For open-ended question 2, the students shared honest reflections on what they disliked about the videos. Some of the comments from students are as follows:

"I am not able to interact with the teacher so if I do not understand, I only can refer back to the videos and notes"

DEEE Year 1, Anonymous

"Despite being step-by-step, I feel that it is really not the same as us doing the experiment itself and I feel that I would need to actually do the experiment to be able to understand and remember the materials better."

DEB Year 2, Anonymous

For open-ended question 3, the students shared their opinions on what they think could be improved (in the context of lab videos). Some of the comments from students are as follows:

"lab videos should be more interesting and interactive……."

DCPE year 1, Anonymous

"Carry out lab experiments videos like actual lessons, like a pov of a student listening and doing the lab experiment"

DEEE Year 1, Anonymous

The survey done by more than 300 students across all diplomas and levels provides good insights into the usefulness of the e-practical videos, characteristics of the e-practical videos and what can be improved in the future. From the results, it shows that the videos are useful for the students while studying at home online. The short videos enable the students to enhance their learning and allow them to review the content anytime and anywhere. For future lessons, interactivity of the videos will be improved to eventually allow it to mimic the actual practical session.

TSA STAFF SURVEY

In this work, the technical executives from TSA division played a critical role in the lab video production. In the absence of their commitment and willingness to go the extra mile during this challenging time, the students' learning would have been affected. This section of the manuscript centres on them and understanding their mind-set during COVID-19 period.

This survey captured the feedback from all 41 technical executives in TSA division.

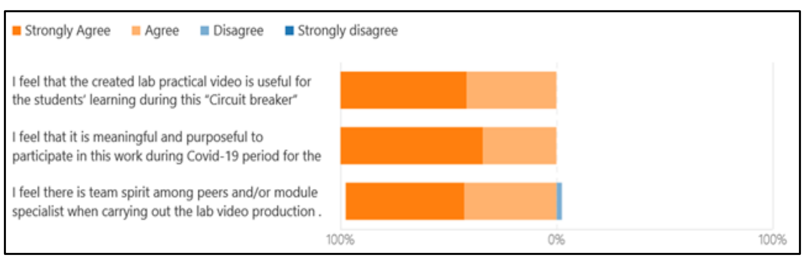


Figure 6. Mind-set and teamwork

The survey from Figure 6 shows a strong sense of commitment among the TSA staff and all of them feel they are making a difference in influencing the students' learning. 100% of the staff agree (56% Strongly agree and 44% Agree) that they think the e-practical videos created are useful for the students' individual learning. All of them (63% Strongly agree and 37% Agree) also felt it was meaningful and purposeful even during the challenging period to return to school to fulfil this part of the work. From the survey, there is a strong sense of team spirit (95% Strongly agree and agree) within the TSA group and specialists. This is the key reason why the school was able to tackle the challenge of COVID-19 head-on and maintain academic rigour for our students.

In the following section, feedback from the TSA staff were consolidated and presented. The open-ended questions allowed us to gain better insights into the TSA staff motivation in the lab video production.

Findings from responses collected from open-ended questions

Question: What motivates you to return to campus to carry out the lab video production?

"Knowing the importance and purpose of creating the lab video is to let students who are unable to come to campus a head start or giving them a general idea of the experiments"

Don, Ng Kheng Ann (TSA)

"Felt this was the next best option for students to reinforce their knowledge and have a better understanding of the subject, without having physical access to the lab equipment."

Chu Tee Khiang (TSA)

"As a parent, I would like my children (students) to learn as much as they can. This is my motivation.'

How Seo Tin (TSA)

"For Covid19 pandemic to allow student walk through the lab."

Tan Chin Hee (TSA)

"For the benefit of the students"

Malek (TSA)

"It is my duty to do it. At least students have alternative ways of learning during Circuit Breaker period."

Chong Wee Tat (TSA)

RELECTION AND FUTURE WORKS

The widespread cases of COVID-19 around the world results in several challenges and disruptions to everyone normal livelihood. For an education institute, the ways we commonly reach out to our students and how they can learn through hands-on experiments are now impacted due to COVID-19. During this difficult time, there is always a choice in not doing anything and waiting for the pandemic to pass. However, there is no certainty how long the virus will last. The longer it takes for the society to return back to normalcy and for students to return back to school, the greater will be the learning gap of our students if no mitigation measures were carried out.

Reflecting back to the period where the School of EEE is closed during CB, we are heartened by the positive mind-set demonstrated by our staff (as shown from survey in Figure 6) and the willingness shown in going the extra mile to carry out measures required to reduce the disruptions towards our students' learning. The created e-practical videos were also deemed useful by student (Figure 4 and 5) which supported their learning during this difficult time.

Looking ahead, the created e-practical videos bring many benefits for the students in the School of EEE and are not limited to only the COVID-19 period. The students can use them for self-directed learning during normal school time and they can go at their own pace as they improve their knowledge of the different practical sessions across modules.

For future works, the school will build on this strength to improve the e-practical videos to achieve level 2 and level 3 interactions. The e-practical videos open up many exciting opportunities for the school. This includes enabling the School of EEE to explore full HBL across the semester to utilize the strength of e-practical videos complementing online asynchronous lectures, synchronous tutorials and assessments that we have developed during this time. The learning focus will then be on mastery in skills practice during the actual lab sessions as instructional procedural steps can be learned through the use of the lab videos beforehand. When there is a need to catch up with the practical, the lab sessions can be redesigned to be carried out in a shorter time by combining what were previously two weeks of lab sessions into a single one to optimize the time that students spent in the lab for their learning.

CONCLUSIONS

This paper presented the collective approach from School of EEE, Singapore Polytechnic in addressing the challenges posed by the restriction due to COVID-19 for full home-based learning. Practical lab lesson is an important aspect for an engineering school for students to gain equipment knowledge and hands-on experiences. In order to lessen the impact on students' learning and to continue upholding the academic rigour required of an engineering school, much effort was devoted for the dissemination of the e-practical videos to the students during the “Circuit Breaker” period. The lab videos encourage students to cultivate self-directed learning giving them the flexibility to learn at their own pace.

Results from survey shows that the lab practical video were useful for the students in connecting theoretical knowledge to practical “know how” during the COVID-19 CB period. Moving ahead, the successful deployment of e-practical videos leads to more opportunities for both manpower and resource optimization for the school as we look beyond COVID-19.

ACKNOWLEDGEMENTS

This manuscript is dedicated to all the Technical Executives (TSA) and the Specialists (TD) in the School of EEE, Singapore Polytechnic and the authors wish to highlight their contributions. The school is highly appreciative of their hard work and sacrifices made during the “Circuit Breaker" period. It is through their collective effort during this challenging time that the impact to the students' learning was greatly minimized, and this piece of work for the students was made possible.

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BIOGRAPHICAL INFORMATION

Boon-Seng Chew received his B.Eng. degree and Ph.D in electrical and electronic engineering from Nanyang Technological University, Singapore, in 2005 and 2013 respectively. He joined Defence Science Technology Agency of Singapore (DSTA) in 2010 as a system engineer and was appointed as a senior engineer. He left DSTA in 2013 and return to his alma-mater and is now serving as a manager and T&L (Mentor), Singapore Polytechnic, School of Electrical and Electronic Engineering. His research interests include teaching pedagogies, 3D graphics/animation compression and transmission, signal processing and multimedia application.

Boon-Chor Seow received his B.Eng. degree and Master of Science in electrical engineering from National University of Singapore, in 1984 and 1998 respectively. He have in-depth experiences in the domain of PCB and product testing. He joined National Semiconductor Pte Ltd in 1984 as a product test engineer and was a PCB and System test engineer with Unisys International Pte Ltd in 1987. In 1991, he joined Hewlett Packard Pte Ltd as PCB test engineer. He joined Singapore Polytechnic as a lecturer under School of Electrical and Electronic Engineering in 1992. He is currently a manager and in charge of school events organisation such as technical conferences and project exhibition to showcase staff and students' capability and to enhance students' learning experiences in the School.

Chee-Seng TAN is the Centre Director of SP's 5G & AIoT Centre. One of his key responsibilities is to drive the Artificial Intelligence of Things (AIoT) initiative and development in SP. Chee Seng has experience in working with industry partners, launching the SP Smart Connected Solution Laboratory that trains both full time students and adult learners on Internet of Things and its application, where he is also one of the trainers. Chee Seng is an accredited Amazon Web Services (AWS) Educator too. Before joining SP, Chee Seng worked at STMicroelectronics as a project manager and lead engineer. He has more than 10 years of experience in the field of Digital Video Broadcasting.

Hwang-Keng Leck is an Assistant Director at the School of Electrical & Electronic Engineering, Singapore Polytechnic. One of her key responsibilities is to manage the learning facilities and build up the capabilities of the Technical Executives to support the full-time courses and continuing education & training (CET) courses in her school. She oversees the planning and upgrading of learning environment with innovative features to improve student's learning productivity. Her current focus is on encouraging innovation in laboratory operation to enhance student's engagement and learning of engineering skills inside and outside the laboratory classroom.

Chow-Leong Chia 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.

Ser-Khoon Toh 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.

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ADAPTING CDIO FRAMEWORK TO CULTIVATE SELF-DIRECTED LEARNING DURING COVID-19 PANDEMIC

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ABSTRACT

One of the goals of the School of EEE is to cultivate self-directed learning (SDL) mind-set in all its graduates with its holistic SDL eco-system, whatever the situation. The coronavirus pandemic required changes to its implementation of curriculum delivery. Campus closure in April to June 2020 forced the switch to full Home-based Learning (HBL) in the form of online asynchronous lectures, synchronous online tutorials, e-practical lessons, and e-proctoring assessments to enable students' learning to continue. This paper discusses how the cultivation of SDL continued to be the main focus of the School through the effective deployment of HBL and guided by the various CDIO Standards despite the ravages brought about by the pandemic. This resulted in the transformation from the traditional learner-centric classroom delivery to learner-centric HBL, minimising the impact on learning outcomes (Standard 2) and yet cultivating the SDL mind-set for 2400 full-time and 650 part-time students. Previously developed learning contents for face-to-face delivery were converted to asynchronous form, with close follow-up by the teaching staff of their students during the synchronous online tutorial lessons for active learning (Standard 8). The School also capitalised on the free trial of add-in for PowerPoint, enabling increase student interactivity through their inputs and feedback on a single platform during synchronous online tutorial lessons. The use of learning analytics to provide teaching staff with real-time visual feedback on the students' learning ability was also carried out. Lab practical videos, together with the deployment of appropriate simulation software where available, were used so that students could learn the practical experiments/projects although the lab venues were not accessible (Standard 6). Regular learning assessments (Standard 11) were conducted online with e-proctoring to ensure students were progressing and coping well despite campus closure. Training of teaching staff to enable them to conduct online synchronous lessons effectively (Standard 10) was conducted as the majority had previous little experience in online teaching. Various survey results are shared in this paper, and these affirm that student learning can continue in the new norm of engineering teaching and learning, with on-going improvements. The changes necessitated by the curriculum transformation needed to ensure that student learning continues in the face of restrictions brought about by the coronavirus pandemic, though overwhelmingly challenging at times, are catalytic to help shape our students to become self-directed learners. It drives home the point, that this need for SDL is even more urgent in the new norm of teaching and learning.

KEYWORDS

Self-Directed Learning, Learning Analytics, Whole-school, Standards: 2,6,8,10,11

INTRODUCTION

A newly identified coronavirus, SARS-CoV-2, has caused a worldwide pandemic of respiratory illness, called COVID-19. It is highly infectious with many healthcare systems around the world struggling to cope. This had led to drastic steps of lockdown imposed in many countries, affecting schools and educational institutions as the in-campus face-to-face lessons could no longer be conducted.

Prior to the coronavirus pandemic, the School of Electrical & Electronic Engineering (SEEE) already has in place an enhanced engineering education model that aims to produce graduates who are independent and self-directed in their mindset with a distinctive metacognitive skillset. This involves a comprehensive whole school approach that starts on the day when a student joins the school right up to the final year examinations.

The school firmly believes that having a self-directed learning mind-set is indispensable for one to be work-ready, life-ready, and world-ready in order to succeed in the 21st century. With this belief, elements of self-directedness are infused in all activities that a student is exposed to throughout the three-year course of study, either through formal or informal means, structured or non-structured ways, and within or outside of the school environment.

To assess how well the curriculum has succeeded in moulding the students to be self-directed, three SDL surveys were conducted on the first batch of students starting in April 2019. The results, discussed later in this paper, affirmed the measures taken by the school in the infusion of self-directedness were on the right track (Toh, Chia, Tan, & Safura, 2020).

SCHOOL-WIDE RESPONSE TO COVID-19 PANDEMIC

With the onslaught of the coronavirus spreading ferociously across the world in early February 2020, the polytechnic started to implement contingency plans to prepare for the day when the virus reached Singapore's shores. Preparations were implemented for the worst-case scenario where a complete lock-down had to be imposed in the country to contain the spread of the virus and HBL had to be implemented. The convened School's task force had identified the following areas to focus on in order to educate and train the students to acquire a SDL mind-set and a metacognitive skillset without compromising on the academic rigour, quality of assessment and student engagement:-

- Asynchronous lectures and synchronous online tutorials (Standard 8)
- E-practical lessons (Standard 6)
- E-proctoring assessments (Standard 11)
- Using real-time feedback for formative assessments (Standard 8)

The asynchronous lectures and e-practical lessons required the students to self-learn and this would lead to strengthening their SDL mind-set while the synchronous online tutorial lessons helped the students by hand-holding them to understand difficult concepts. The real-time feedback allowed the teaching staff to pinpoint the areas that students were weak in so that help could be rendered in the appropriate areas during the synchronous online tutorials as a form of safety-net. The e-proctoring assessments served to validate the overall quality of students' learning.

When the worst-case scenario of campus closure became a reality on 7 April 2020, the earlier decision to transform all learning contents into HBL proved to be fortunate on hindsight. On 18 June 2020, Phase 2 replaced the lockdown with safe management measures that included mandatory wearing of face mask in public, safe-distancing measures at all times and in all places, and with a maximum of five persons allowed to gather at any one time. This meant that students could return to campus but in controlled numbers. For laboratories, they were rostered for half class size of 10 to 11 students each time, instead of the full class size of up to 22 students. However, all lectures and tutorial lessons continued in the same online manner as during the lockdown.

ASYNCHRONOUS LECTURES AND SYNCHRONOUS ONLINE TUTORIALS

In the first semester of the academic year (AY) 2020/2021 starting in April 2020, there were altogether 130 modules offered across all five diploma courses school-wide. Out of this total, six were available online with fully developed asynchronous learning contents. Students taking these modules understood that they were expected to learn through blended flipped learning. The other 124 modules were supposed to be taught face-to-face in the campus based on three components – namely lecture, tutorial and practical. However, this was no longer possible due to the lockdown and hence all the modules were converted to blended flipped learning. It was thus a golden opportunity provided by the pandemic to accelerate the conversion of these 124 modules to blended flipped learning as any earlier reservation pre-pandemic, over their implementation fizzled out.

Asynchronous Lectures

The School had adopted the CDIO Standards as the guiding principles in the development of its curriculum. With the conversion to HBL, the Standards were again heavily referenced to ensure the students continue to be engaged directly in thinking and problem-solving activities (Standard 8) albeit in a virtual setting. To develop a fully flipped module on par with the six that were already available, the school understood that time was the essence. With the limited time available to achieve the same level of readiness as in a complete blended flipped learning module, the school had decided to adopt a framework to prepare staff based on the readiness of the online learning materials as given in Table 1.

Table 1. Definition for different levels of flipped learning materials

Category	Flipped Learning Materials	Objectives
Level 1	PowerPoint slides with voice over narration only/edited videos recorded during lessons in bite sizes	Self-learning by accessing online learning materials anytime, anywhere
Level 2	• Bite-sized PowerPoint slides with voice over narration only/edited videos recorded during lessons/Articulate Rise 360 with embedded voice & videos • Self-assessment quizzes at the end of each segment • Readiness check at the end of the topic	Available information based on the students' learning is used for data analytics to facilitate differentiated teaching where not only the weaker students are helped but the better ones are also stretched to realise their full potential
Level 3	• Animated graphics • Interactive branching scenarios • Interactive videos and audios	Designed to simplify the understanding and explanation of complex and abstract principles/ theories

The conversion to blended flipped learning started about a month before the lockdown was imposed and when the semester started, HBL learning materials were available for at least the first five lessons in all modules. Work on the conversion continued as the semester progressed and all modules were fully converted to Level 1 before the end of the semester in August 2020. The success of the implementation of the asynchronous lectures in Semester 1 gave the School a much-needed boost and raised its confidence to phase out face-to-face lectures and replacing these with asynchronous blended flipped learning. This would become the new normal going forward. Meanwhile, the teaching staff began work on the Level 1 modules with the aim to enhancing it to meet the requirements of Level 2.

Synchronous Online Tutorials

During the lockdown in Term 1 of Semester 1 (April-May 2020), lecturers were conducting full-blown online synchronous lessons for the very first time for all modules. As could be expected, many lecturers were uneasy and uncomfortable through lack of experience. Those who were averse to using technology faced even greater challenges. Nevertheless, many of the dedicated and committed lecturers compensated their lack of confidence in conducting virtual lessons by spending longer than the allocated time to conduct their online lessons. Initially, many were under tremendous stress but as the weeks went by, the lecturers slowly adapted to the new way of conducting lessons and this became more manageable for them. It also helped that most of the lecturers were prepared to engage their students outside of the allocated lesson hours to help their students learn.

The Teaching & Learning (T&L) Unit provided the necessary support by conducting workshops on how to conduct effective online lessons, focussing on students' interaction and engagement. The Unit also introduced two other measures to make conducting synchronous online lessons less daunting - the use of a newly available PowerPoint add-in called ClassPoint and the purchase of computer-writing pads with stylus pens. ClassPoint is a student response system (SRS) like Kahoot, Socrative and Mentimeter but its advantage lies in its seamless integration with PowerPoint, unlike other SRSs that were based on different platforms. The computer-writing pads with stylus pens made it possible for the lecturers to complement verbal explanation with written illustration during online lessons. However, the School is mindful that technology is only a tool, and that the student is at the heart of the teaching and learning initiatives (Loh, Lim, & Sun, 2021).

E-PRACTICAL LESSONS

The School's curricula is fully supported by engineering workspaces for all components of hands-on, knowledge, and skills learning (Standard 6). With the lockdown, the hands-on component was temporary suspended. However, the School was optimistic that the lockdown was a short-term measure that would be lifted eventually. With this in mind, lab practical videos were developed for all the modules that required the use of laboratories in conducting practical lessons. The lab practical videos aimed to familiarize the students with the individual experiments. These included recorded procedures such as equipment and lab setup, how to use different equipment and carrying out the individual experiments. With campus closure, the lab practical videos provided students with a viable alternative to learn about the practical aspects of their modules. The durations of these videos were deliberately kept short as the objective was on micro-learning (Lindner, 2007), for better emphasis on the key content areas.

With Phase 2 implemented in June 2020, lab practical sessions that were missed during the earlier campus closure in Term 1 resumed for students but in controlled numbers. Having accessed and viewed the lab practical videos earlier, the students were able to complete each lab in less time than would have been needed previously as the usual time needed for the lab briefing at the start of each lab session have also been partly covered in the lab videos. In short, the usual two-hour duration for a typical lab session needed in the past could allow for two different experiments to be combined and conducted during the same time, thus minimising the impact for the students who missed out on the practical lessons during the earlier campus closure.

The School categorized lab practical videos into three different levels based on the depth of learning in comparison to the physical hands-on lesson with reference to Bloom's Taxonomy as given in Figure 1. This is not to be confused with the levels accorded to the development of the asynchronous learning contents.

Although students were able to return to the laboratories to conduct the experiments, teaching staff continued to work on improving the lab videos from Level 1 to Level 2 so that these could be more informative and could become part of the future training to instill self-directed learning in the students.

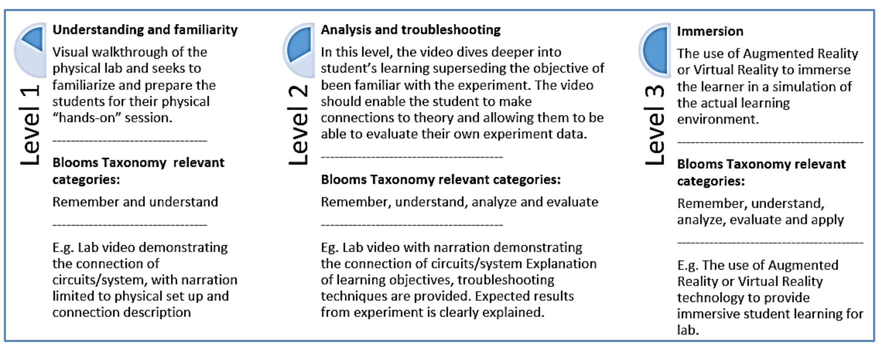


Figure 1. Categorization of E-Practical Videos

E-PROCTORING OF ONLINE ASSESSMENTS

The need for constructive alignment between learning outcomes and aligning of both teaching and learning activities and the assessment activities, is integral to ensuring the quality of a good course design and delivery. Assessments are thus inseparable from the teaching and learning activities as Standard 11 states that assessment of student learning is the measure of the extent to which each student achieves the intended specified learning outcomes. There was a plethora of alternative assessments (Gordon, 2020) suggested that could be considered. Although the School decided to continue with the usual assessments as most of those suggested could not meet the need for constructive alignment mentioned earlier for many of the engineering modules taught, these assessments had to be converted to online versions.

The two forms of alternative innovative assessments that were put in place were: COVID Formative Assessment (cFA) and COVID Mid-Semester Test (cMST), with the former being fully online small-stakes assessments conducted during Term 1, and the latter being the fully online version of the usual paper-based mid-semester test conducted at the end of Term 1. The cFA would apply to about 92% of all modules, or 130 modules, while the cMST applied to 73% of modules, or 102 modules, when implemented.

To ensure the academic integrity of the remote online assessments, many factors were considered for the implementation of the cFAs and the cMST. These included the elements such as “unstructured” short questions that test on analysis and application with answers not easily obtained using online search, no backtracking, one question shown at a time, randomness of question and randomness of answers, as in the case of multiple-choice questions, as recommended (Budhai, 2020) (Weleschuk, Dyjur, & Kelly, 2019) (Ragupathi, Jan 2020). Another key consideration was the use of online proctoring, an essential feature for assessments to minimise cheating, and as a preventive measure to prevent such incidents from taking place as these had happened in other IHLs (Dyer, Pettyjohn, & Saladin, 2020) (Sun, 2020).

There was a need also to get buy-in from the school’s various stakeholders; staff, students and parents, and to initiate appropriate change management to bring it about. The process had to be made palatable for staff who were already saddled with HBL and had to be convinced of the need to have the new assessment process, albeit remotely, assessment being an integral part of student learning. Further, to ensure the smooth conduct of the process, relevant training by the school’s Teaching and Learning team had to be conducted.

Mindful that students were undergoing e-proctoring for the first time, the school stepped up various measures to prepare them. That entailed coaching them on the new process, looking into whether they were equipped in terms of the computer devices and handphones, with home network access, and giving attention to those with special needs, who were uncomfortable or had difficulty with the demands of remote e-proctoring.

Parents had to have their fears allayed as they were concerned about the adverse impact that the new process might have on their child’s performance. Given the very short lead time (two weeks) within which the school had to address those challenges, and above all, to come up with a solution that not only would do so, but was also affordable and had a quick turnaround, it was, indeed, a daunting task, to say the least.

USING REAL-TIME FEEDBACK IN FORMATIVE ASSESSMENT DURING HBL

The School also started a project based on a technology-driven framework to incorporate the application of EduTech tools and data visualization software to facilitate learning of students’ performances. This is in line with Standard 11 that covers the assessment of student learning. The aim is to equip teaching faculty with both pedagogic and technical capabilities in using EduTech and the students’ formative test data to derive learning insights. These insights are then used to implement subsequent learning interventions to enhance student learning (e.g. attainment, engagement).

The following broad methodology was used in the project intervention strategy:

1. Students do a readiness test on student response system (Socrative) before class contact time
2. Students take a 30-minute time-tabled schedule cFA as described in the earlier segment
3. Students complete a 1-minute short exit poll before end of synchronous online tutorial lesson on Microsoft TEAMS
4. Lecturers analyse the data further via Power BI Dashboard and plan for intervention actions during synchronous online lessons

The process is illustrated in Figure 2.

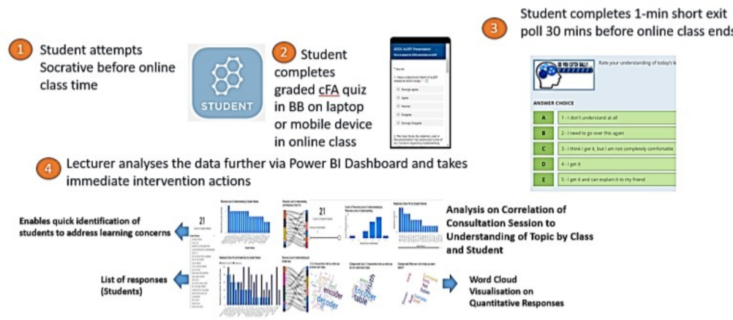


Figure 2. Real time student feedback process

SURVEYS OF STUDENT VIEWS ON THEIR LEARNING AND THE IMPACT ON SDL

Several surveys were administered to find out how the students were coping with the changes implemented. For the HBL surveys on the asynchronous and synchronous online lessons, these were conducted at the institutional level while the surveys on lab videos, online cFA and cMST assessments were conducted at the school level.

Surveys on HBL Asynchronous and Synchronous Online Lessons

Surveys were conducted at mid-semester (June 2020) and at the end-of-semester (August 2020). These required all School of EEE students to feedback on all modules that they had taken. This means that if a student were taking four different modules, he would have given four responses. For the whole School, the total responses received were 5847 and 7329 for the mid-semester and end-of-semester, respectively. Both surveys consisted of two common statements related to student learning and engagement, with a 6-point Likert scale and another question that sought feedback on areas of improvement.

E-learning/lecture materials for the asynchronous online lessons had been effective for student learning

The results in Table 2 and Figures 3a and 3B show more than 84% of the students felt that the e-Learning/lecture materials were effective for their learning.

Table 2. Results of surveys on effectiveness of asynchronous learning contents

	Mid-Semester	End-of-Semester
Average score out of a 6-point Likert scale	4.44	4.44
Percentage of students generally felt that the e-Learning/lecture materials were effective for their learning	86% (Total=5847)	84% (Total=7329)

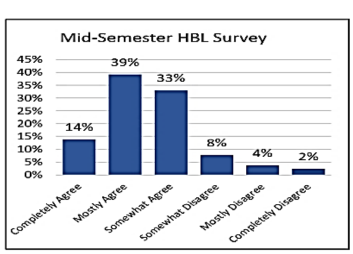


Figure 3a. Results of mid-semester survey

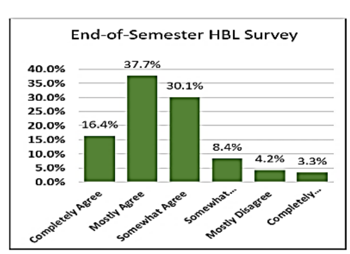


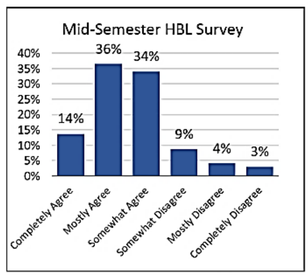
Figure 3b. Results of end-of-semester

Synchronous "live" online lessons had been effective for student learning

More than 81% of the students felt that the synchronous online lessons had been effective for their learning as shown by the results in Table 3 and Figures 4a and 4b.

Table 3. Results of surveys on effectiveness of synchronous online lessons

	Mid-Semester	End-of-Semester
Average score out of a 6-point Likert scale	4.37	4.32
Percentage of students generally felt that the synchronous "live" sessions are effective for their learning	84% (Total=5847)	81% (Total=7329)



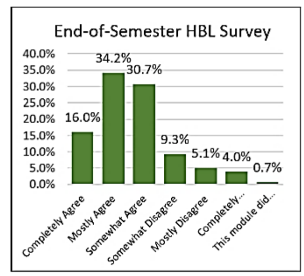


Figure 4a. Results of mid-semester survey Figure 4b. Results of end-of-semester

Areas that have supported students well in modules during HBL

The top three areas that have supported the students well during HBL as shown in Figure 5 were:

- Sufficient learning contents (e.g. lecture notes)
- Easy to access and navigate e-learning/lecture materials
- Clear and easy to understand online learning materials

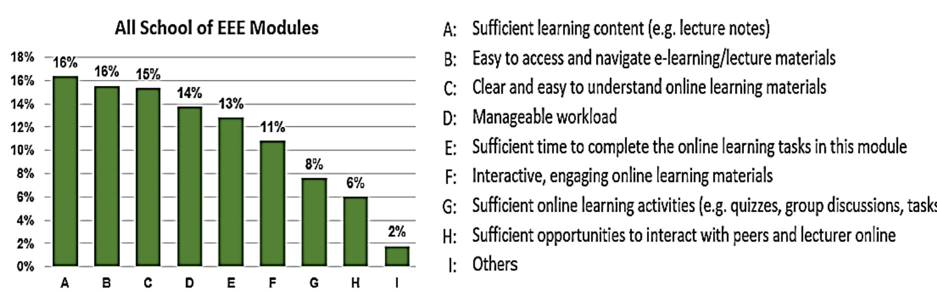


Figure 5. Areas that contributed towards students' HBL learning

Survey on E-Practical Lessons

A school-level survey involving more than 300 students from all years of study gave their feedback on the effectiveness of using the lab practical videos for their learning. Each question in the survey was measured using the 4-point Likert Scale format (Strongly Disagree, Disagree, Agree and Strongly Agree) with open-ended questions at the end.

In Figure 6a, 80% of the students strongly agreed and agreed that the videos were useful in helping them to connect the theoretical knowledge they gained from the asynchronous learning contents and synchronous online tutorial lessons. This is important especially in an engineering context where theoretical knowledge gained will not suffice if the students want to find solutions to solve real-world problems. The 84% of the students strongly agreeing and agreeing in Figure 6b on the usefulness of videos as reference when doing the actual lab experiments aligned with the intended purpose of the lab practical videos.

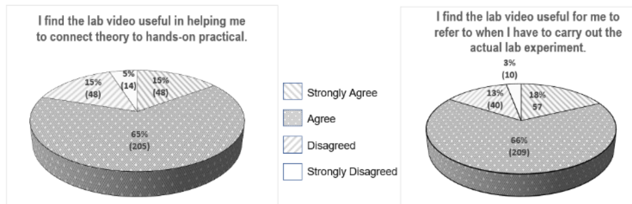


Figure 6a. Connecting theory to hands-on practical
Figure 6b. Familiarity with actual lab experiment

During the creation of the lab practical videos, the length of the videos were kept intentionally short to enable "bite-sized" learning. This provides the flexibility for students to focus on the specific parts of the lab practicals which they are not familiar with, and to watch and review any specific sections again anytime they wish. As shown in Figure 6c, 86% of the students strongly agreed or agreed that the duration of the videos were just right.

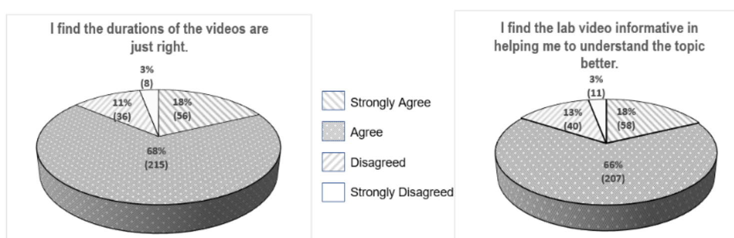


Figure 6c. Aspect of Micro-learning Figure 6d. Understanding of topic

A total of 84% strongly agreed and agreed that the lab practical videos were informative and helped them to understand the topics better as shown in Figure 6d. However, Figure 6d reveals that 16% of the students thought otherwise. This could be addressed in future work as these videos could be improved to make them more useful for students' learning by incorporating aspects that engage them in higher order thinking and repetitive practical tasks, as more Level 2-type and Level 3-type lab practical videos would be created. Through virtual "hands-on" and improvement in details of the videos, better knowledge transfer and learning efficiency could possibly be achieved.

Survey on E-Proctoring Assessments

A school-level survey, consisting of 3 statements related to the assessments, with a 4-point Likert scale and two open-ended questions, was administered soon after the completion of the cMST in June 2020. A total of 338 valid completed responses was received.

Figure 7 shows the responses of the students on their views of the online assessment. 26.3% of the students strongly agreed that the regular assessments help them to keep pace with their learning, while 61.2% agreed on this. Combined, about 12.5% disagreed and strongly disagreed to this.

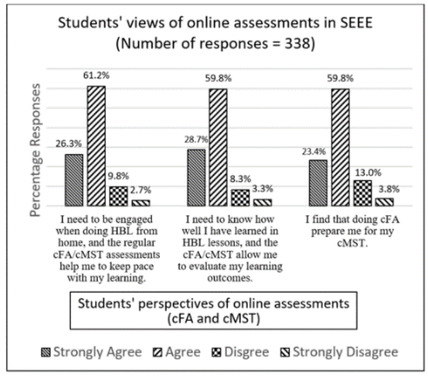


Figure 7. Results of Online cFA and cMST survey

A slightly lower percentage of 59.8% of students agreed on whether the cFA allows them to evaluate their learning outcome and how well they have learnt while another 28.7% strongly agreed to this view. The combined 11.6% of students who disagree and strongly disagreed is lowest here. On the statement that doing cFA prepare students for the cMST, this recorded the highest combined percentage of 16.8% who disagreed or strongly disagreed.

Summary of Survey Results

Based on the summary given in Table 4, the results suggest that the School's quest to build an alternative ecosystem to support teaching and learning on a virtual platform is moving in the right direction as the students had given their endorsements based on the feedback received. This means that the students have accepted the asynchronous lectures, synchronous online tutorial lessons, and e-practical lessons as the new normal in their learning. With acceptance, they would tend to put in efforts to become more engaged in their online learning and this could only lead to positive outcomes. Indeed, as the students became more effective in their independent and self-learning, they had also strengthened and raised their SDL competency to a higher level. This encouraging result was further affirmed as similar academic performances for all modules were obtained at the end of Semester 1 in 2020, not unlike those in the preceding years prior to the pandemic.

Table 4. Summary of results of the surveys

Survey Questions	Agreed
Effectiveness of HBL asynchronous online lessons	85% (average)
Effectiveness of HBL synchronous online lessons	82.5 (average)
E-Practical lessons helped in connecting theory to hands-on	80%
E-Practical lessons helped in familiarising with actual lab experiment	84%
Lengths of e-Practical videos were just right for micro-learning	86%
E-Practical Lessons helped in the understanding of topic	84%
Regular assessments helped to keep pace with learning	87.5%
Regular assessments allowed evaluation of learning outcomes	88.5%

SURVEY ON SDL INDEX MEASURING PROGRESSION IN SELF-DIRECTEDNESS AFTER TWO YEARS

The results of this undertaking after two years of implementation is shared here. The students in Year 1 of cohort 2019/2020 were asked to participate in three self-assessments surveys so far; one when they first joined the School, a second and third respectively at the end of the first and second academic years. This is to investigate the students' SDL readiness at different milestones of their studies. Results from the first two surveys (at start and end of first year of studies) were shared previously (Toh, Chia, Tan, & Safura, 2020).

The self-assessment survey consists of 14 statements (see Table 5) on a 7-point Likert scale. 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.

Table 5. Students' Self-assessment Statements for SDL

Statements S1-S2 Intrinsic Motivation	
S1	I prefer learning materials that really challenge me so I can learn new things.
S2	I prefer learning materials that arouse my curiosity, even if it is difficult to learn
Statements S3-S4 Extrinsic Motivation	
S3	I want to do well in my studies because it is important to show my ability to others.
S4	Getting a good grade is the most satisfying thing for me.
Statements S5-S14 Dimensions of Self-directedness	
S5	I set learning targets for myself.
S6	I normally ask questions when I am not sure about my learning.
S7	I always look for more information to help me understand better.
S8	I always make a list of what I need to do for my learning.
S9	I usually complete my assigned tasks on time.
S10	I often try to understand where I go wrong in my learning.
S11	I try different ways to solve problems on my own at all times.
S12	I have a habit of applying what I learned to other topics or areas.
S13	I always seek out what is required of me beyond the syllabus of my module.
S14	If I try hard enough, I will understand the learning materials.

In terms of intrinsic motivation based on the plot given in Figure 8, the students have shown positive improvements. For example, for S1, there have been an increase of 9% at the end of the second year. Likewise, for S2, it jumps from 56% to 69% meaning an increase of 13% of the students are motivated enough to want to learn out of curiosity regardless of the difficulty level. Similarly, in terms of extrinsic motivation based on S3 and S4, improvements are also evident as the percentages rise from 59% to 64% and 68% to 78% respectively in relation to showing one's ability to others and personal satisfaction in getting a good grade.

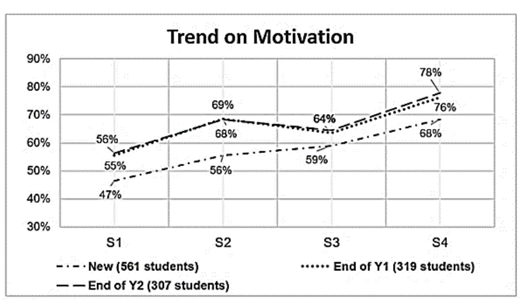


Figure 8. Students' self-assessment indicating heightened motivation

Figure 9 shows the results for all other statements (S5 to S14) evaluating the dimensions of self-directedness in the students. It is noteworthy that the overall trend shows the students have progressed well over the two years. Compared to the time when they first joined the school, much progress was made at the end of the first year and further strengthened at the end of the second year. The improvements ranged from 12% to 23%.

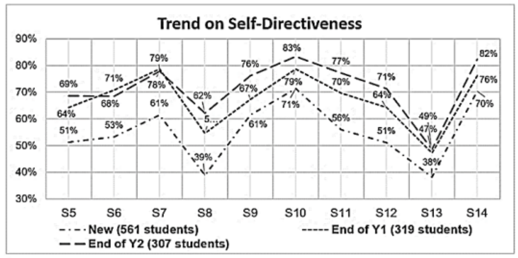


Figure 9. Students' self-assessment indicating heightened self-directedness

The biggest improvement of 23% was for S8 indicating that many of the students always make a list of what they need to do for their learning. Another notable jump of 21% was for S11, highlighting that students have developed the good habit of trying different ways to always solve problems on their own. There was also an increase in the number of students who sought to apply what they had learned to other topics or areas as S12 had garnered an improvement of 20%. The only drop from the end of first year to end of second year was in S6. A possible factor could be with the replacement of face-to-face with asynchronous lectures, students could now access online learning materials at any time of their learning without the need to refer to their lecturers to ask questions.

CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

Based on the work done during the pandemic with regards to the blended flipped learning materials for asynchronous lectures, synchronous online tutorials, e-practical lessons, and e-proctoring assessments, this heralds the opening of many exciting opportunities for the School. This includes enabling the school to explore full HBL across the semester to further optimize on the lab practical videos, online lectures and assessments that were developed.

Through the implementation of the fully online assessments and conducted through remote e-proctoring means, the School has gained useful experience and confidence, and nimble enough to adapt to the new online teaching and learning environment in a relatively short time. Conducted with the aim of engaging students in their learning, the innovative online assessments have enabled evaluation of learning outcomes by teaching staff, and students themselves, through constructive alignment of desired learning outcomes and re-designed teaching and learning approaches, while upholding the high standards of both academic rigor and academic integrity. The views and responses of the students are useful inputs to be considered for improving the implementation to bring about even greater student engagement going forward.

The findings from the self-assessment surveys by the students have affirmed the cultivation of SDL and showing the whole-school approach is progressing on the right track. When the pandemic struck at the beginning of their second year of study, the students were able to cope well as they had developed a certain degree of self-directedness in their first year. This certainly helped when they were forced into a two-month-long lockdown and had to comply with subsequent measures introduced in the classroom for safe-distancing after the lockdown was lifted. Indeed, at the end of the second year in the midst of the pandemic, it is heartening to note that the students' learning had not been affected by the pandemic but instead it had provided them with the opportunity to further strengthen their self-directed learning.

Although most students still very much prefer to have face-to-face lectures, the changed process they have undergone, whether they are conscious and willing participants or not, goes towards cultivating them to become self-directed and life-long learners to ensure continual employability in the twenty-first century workplace. Indeed, results of the SDL surveys have given the School the confidence to continue with the measures introduced during the lockdown even when the pandemic ceases to be a threat. With the asynchronous lectures, synchronous online tutorials, e-practical lessons, and e-proctoring assessments underpinned by the CDIO framework, the School is now ready and fully prepared to face any future pandemic threats without compromising on the cultivation of SDL in its students.

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BIOGRAPHICAL INFORMATION

Toh Ser Khoon is 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. 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. After serving in various portfolios, she presently works with a team of highly experienced and dedicated staff in the Teaching and Learning unit in the School of EEE, who share a common passion to work with colleagues and students alike, so that they become better self-directed learners in all aspects in their own capacities and to role model SDL for others.

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CONTINUOUS ASSESSMENT WITH FLIPPED LEARNING AND AUTOMATED ASSESSMENT

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ABSTRACT

Numerous studies claim that one of the practices that improves student performance is continuous assessment, since it encourages work on the subject and allows for better class performance. Often, this continuous assessment is implemented with 1 or 2 partial exams, which causes an improvement of the performance, but sometimes they become for the students "early final exams" with the consequent disturbance in the usual preparation of the semester. In this article, we describe and analyze a method of continuous assessment implemented in a second-year programming subject of the School of Engineering of the University of Navarra since the 2016-2017 academic year. Moreover, flipped learning approach was introduced in the academic year 2019-2020, with the consequent (but slight) modification of the evaluation method. To implement continuous assessment an automated evaluation tool has been developed both for quizzes and for the correction of programming exercises. The result is a continuous work of the student, good grades and satisfaction from both the students and the teacher.

KEYWORDS

Continuous assessment, flipped learning, automated assessment, programming subject, Standards: 8, 11

INTRODUCTION

It has been stated that the assessment method is what most influences what and how students study (Rust et al., 2005). Studies indicate that it is the most important element of the learning process and should be integrated into it. (Crawley et al., 2014)

Several studies show the positive impact of continuous assessment on academic outcomes (Martín-Carrasco et al., 2014; Pérez-Martínez et al., 2009; Walser, 2015; Cole and Spence, 2012). One of the reasons for this is the increased activity of students, who start working earlier and spend more time on the course (Edström et al., 2003). In addition, it facilitates meaningful learning since new concepts or knowledge are related and build on previous knowledge that, thanks to continuous assessment, are well established.

Often this continuous assessment is implemented with 1 or 2 partial tests, which leads to an improvement in performance, but sometimes they become for the students "early final exams" with the consequent disruption in the usual preparation of the semester.

The summative evaluation for obtaining the final grade, must also include the formative evaluation. This formative evaluation provides teachers and students with data to take the necessary measures and reach the desired level of knowledge (Gikandi et al., 2011).

Some studies establish that continuous assessment favors superficial learning (Jordan, 2009; Tan, 1992). In fact, what favors superficial learning is not the frequency of the evaluation but an inadequate way of carrying it out. The solution is to design tests that not only evaluate basic cognitive skills (Draper, 2009; Leung et al., 2008), which are the easiest to implement with automated systems, but other higher cognitive functions such as analyzing, relating, etc.

Another major difficulty in implementing continuous assessment is the increased workload and time required for teachers to prepare, correct, and score different activities (Reina-Paz et al., 2014). A time that is not motivating for the teacher nor is it valued externally. Trotter's (2006) study recognizes the increased teacher dedication, but states that the results in student motivation and learning are excellent.

At Tecnun, the School of Engineering of the University of Navarra, throughout different curricula and with different calendars, and mainly as a result of the European Higher Education Area adaptation process, we have gone from having only one final exam, to also having intermediate exams, and in some cases biweekly exams were introduced. In addition, in order to evaluate the knowledge with which the students joined the university, diagnostic assessments on the fundamental subjects of mathematics and physics were also introduced. This has resulted in a large percentage of the teachers' time devoted to teaching being spent on correction. A task that, as explained, brings a reduced value to the student and the teacher. For this reason, we decided to work on methods that could relieve the teacher of this workload without giving up the advantages provided by a greater number of evaluations.

EXPERIENCE IN A PROGRAMMING SUBJECT

This article describes and analyzes the implementation of a method of continuous assessment in a second-year programming subject of the School of Engineering of the University of Navarra in the academic years 2016-2017 to 2019-2020.

As mentioned above, it was necessary to develop an automatic correction tool that would adapt to the needs of this subject, which was used for the first time in the 2016-2017 academic year. This is an application in which the teacher defined the exercises that the students had to do at each moment and a program checked the validity of the answer. The system showed the viability of automated evaluation and was moved from two partial evaluations to an evaluation every 10 days. Classroom and home exercises were done and evaluated with the same tool. The students' response was very positive, since it was an optional system in which they could objectively verify their learning process and already have a part of the final grade. (Serrano et al. 2018). In the 2017-2018 school year, the evaluation became weekly.

In the 2019-2020 school year, Flipped-Learning was introduced, along with the need to motivate and verify that students were doing their pre-class work. The following is a description of the course structure as it was developed.

The course is 13 or 14 weeks long depending on the calendar and takes place from the second half of January until the beginning of May, when the final exams of the second semester are held.

The previous structure of the course consisted of a final exam with 2 partial tests, one in the middle of the course and another one two weeks before the end of the course.

With the incorporation of continuous assessment, weekly evaluations were added, resulting in the 2019-2020 course in 9 evaluated practices, 5 before the first partial test and 4 before the second partial test. Also added, with the incorporation of flipped learning, was a weekly theory test. Therefore, with the exception of the first and last week of the course, every week there was an evaluated practice or a partial test and a theory test, so that continuous assessment was incorporated into the students' routine. Figure 1 shows the calendar for the 2020 course, with the evaluated practices marked in dark green and the partial test in blue. The theory tests are marked in light green.

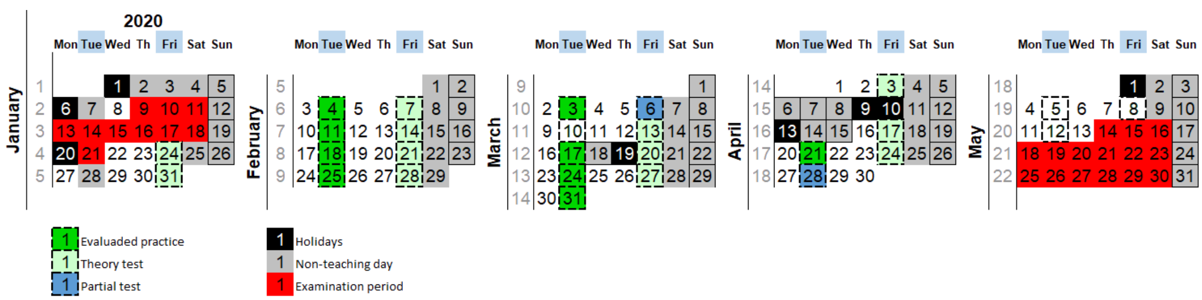


Figure 1. Calendar of the course with the evaluated practices, theory test and partial tests

The course covers 11 or 12 topics, depending on the schedule. These topics are grouped into four blocks: the first of a single topic on computer concepts, the second on the Java language and Object-Oriented Programming which comprises four topics, similar to other courses such as Programming with a Purpose from Princeton University. These two blocks constitute the object of the first partial test. The third block is about the Internet which consists of two topics and the fourth block is about web applications which consists of four or five topics. Block 3 and the first two topics of block 4 are the subject of the second partial tests.

Evaluation mode

Each of the parts has a characteristic type of exercises. The automated evaluator has different procedures for each of these types of exercises. For topic 1 there is a computer processor simulator that is programmed with the instructions written by the students. The evaluator checks that these instructions perform the desired function.

For block 2, the assessor compiles and runs the programs and functions in Java that are written by the students. The automated evaluator checks that the program can be compiled and then executes it taking into account that it may have an error that turns it into an infinite loop, in which case it ends the process and indicates that the solution is incorrect.

In block 3 the evaluator checks that the pages and forms written in HTML language have the elements and characteristics requested in the exercise.

In block 4, where Java applications are written to produce web pages, the evaluator compiles and executes the programs as in block 2. The result is an HTML page that is checked as in block 3.

In addition to the weekly evaluated practices and partial tests there is a final exam and a project in which everything learned in the course is applied. This serves to integrate all the concepts into a larger program and thus the score is not just the sum of evaluations of individual exercises. The final grade is composed of the grade of the first part (25%), the second part (25%), the project (15%) and the final exam (35%). The first part is composed of 5 evaluated practices, the first partial test and 6 theory tests. And the second part is composed of 4 evaluated practices, the second partial test and 6 theory tests.

Automated evaluation

Before the introduction of automated evaluation, the correction of programming exercises was done by viewing and executing the code. The code execution was automated with scripts that made the compilation of the code of each student and the execution with some parameters defined by the teacher to check the correct operation of the program. However, this process was not as direct as described since any error in the execution or a slight variation in the names that the programs should have caused the process to stop.

Automated evaluation in a programming course involves compiling and executing the student's code to check its correct operation. This may seem inconvenient since solutions that fail to compile or run would not be considered here. Here it should be mentioned that, being a second-year programming subject, the need to use “incremental development” suggested by many programming professionals is advised to students from the beginning of the course (Larman, 2003; Downey & Mayfield, 2019). Incremental development consists of obtaining in different iterations applications that work correctly, although it still does not accomplish all the requirements that are demanded of it, until reaching the final code. By introducing the automated evaluation and being able the student to test the correctness of their code from the first exercises, the student acquires from the first days the habit of incremental development and always having an application that works. If not, the student knows that the proofreader won't give any points, whereas it will if the student do a partial but working fix. The student also learns the importance of following nomenclature and spell-checking rules, as if the student does not comply, the evaluator indicates this when evaluating the exercise.

Therefore, we can summarize that the automated evaluation process in a programming subject has the advantage that feedback is provided instantaneously, as it would be produced in a real environment, so that it can be analyze what the error is and be able to modify it appropriately or continue with the next iteration of the program until reaching the final solution.

To define how an exercise will be evaluated, the teacher must: decide whether to evaluate the result of a function or what appears in the standard output captured by the evaluator, provide which are the arguments of the program or the function with which test the student code, indicate the expected answer and the value of the correct evaluation. The teacher can define different checks for each exercise, for example with different values of an argument to check that the student's solution is general. The teacher can also define parameters so that each student's statements are different from those of her classmates. In this case, the teacher expresses the solution as a function of the parameter. The teacher also defines how many tries the student can make for each exercise and whether feedback should be provided at that time. Additionally, question pools can be defined if the teacher wants them to be randomly displayed to each student. Figure 2 shows the definition of a Java exercise by the teacher with how to evaluate it.

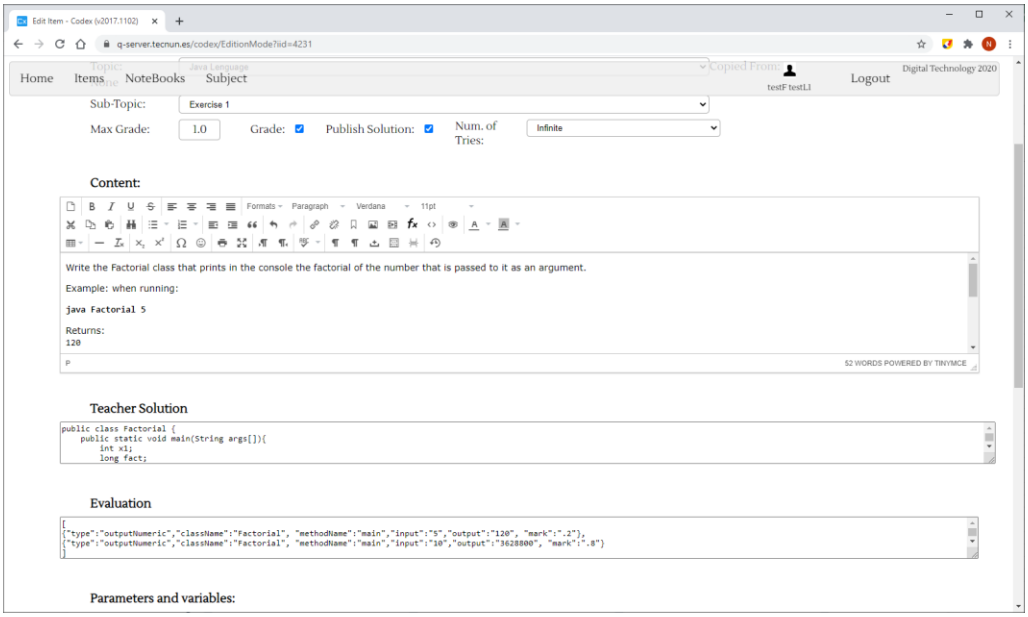


Figure 2. Definition of an exercise

Figure 3 shows the student's view, with the answer that the student introduces and the response of the system when evaluating it.

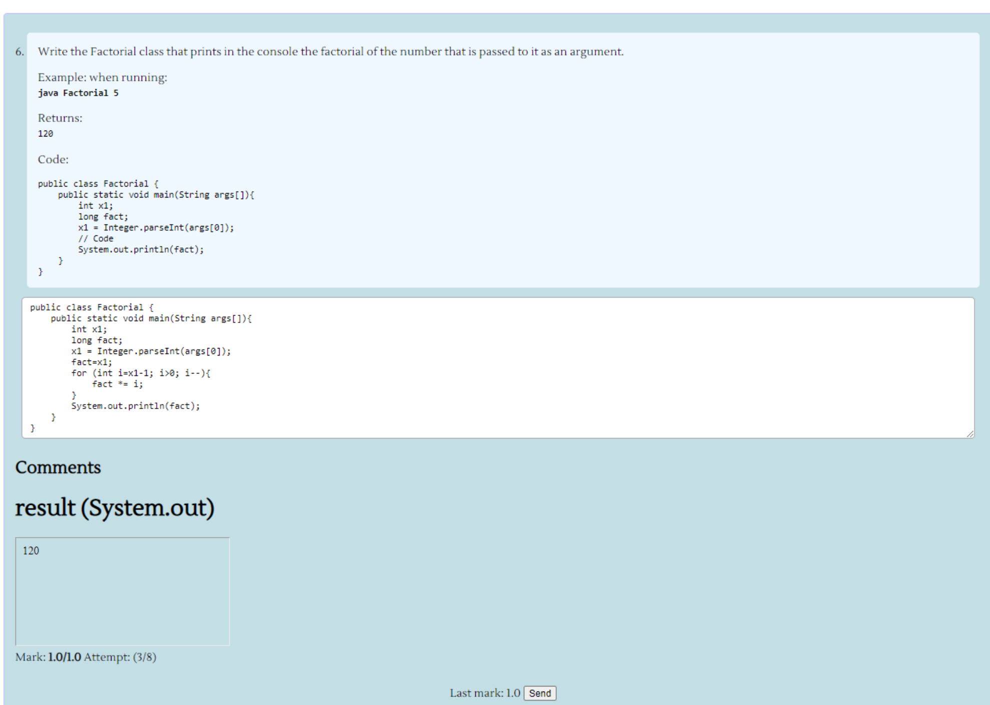


Figure 3. Student view and response of an exercise

Flipped Learning

After the use of the automated continuous assessment in 3 courses, the good results it produced and the good reception among the students were observed. However, the time invested in the theoretical explanations and the evaluated practices left little time for the students to carry out exercises in the classroom. Although they had the automated evaluator to verify the correctness of these exercises, they did not have the possibility to comment them with their classmates, with the teacher or with the assistants of the subject during the class time.

For this reason, Flipped Learning was introduced in the 2019-2020 course, to take most of the theoretical explanations and procedures out of the classroom and to be able to focus the activities on those where the presence of the teacher and students is most valuable. Because the objectives of each class were well defined, having applied continuous weekly evaluation in previous courses, the development of the material, mainly videos, required about 2 or 3 hours of preparation each week for recording and editing, which allowed the flipping of all classes. More than 70 videos are available on the page https://nicolasserrano.github.io/CS/material.

To motivate the visualization of the videos, each week a test was conducted with basic questions from the videos, in which students could take a sheet with their handwritten notes. This has the effect that the evaluation test is done with less tension and the visualization of the videos is done in a more active attitude, and even more comprehensive way than taking notes in class, since the objective is to bring some notes to the next test.

The tests consisted of multiple-choice questions with a correct answer. They were made with the same evaluation tool to have all the marks unified in the same system, but they could be made with the LMS of the subject or another system like Socrative or Kahoot.

It is necessary to mention that since this subject was taught in spring 2020, it coincided with the change to online teaching from March 2020. The classes continued in the same way from that date, the theoretical part continued to be learned through the Flipped Learning videos and the practical classes continued to be the laboratory practices with resolution of doubts. What did occur is a delay in the evaluation tests of both the practices evaluated and the theory tests due to the university's indication not to carry out evaluated tests in the first days of the confinement. When, after two weeks, methods were available to verify the identity and correct performance of the tests, an update of the calendar was published with the dates for the performance of these tests in the following weeks, with the test and the evaluated practice being performed on the same day during the following two weeks.

Since the school wanted to test the proctoring tools in advance before the final exam dates in May, and all the material was available, students of this course were given the option of preparing the material in advance, also advancing the evaluated practices and the tests on the videos in order to take the exam during the class period. It was expected that a dozen students would take this modality, but it turned out that most of them signed up for it. So the school was able to take a most complete test of the proctoring tool.

RESULTS

The result of applying the continuous assessment, as already mentioned in the article on its application in previous courses, has been very positive both in the aspect of learning and student satisfaction. Figure 4 shows the results of the survey carried out with students in February 2018, regarding which exercises were to be maintained with automated evaluation. Only 1 student out of 23 did not want the weekly evaluation, while 95.6% wanted to continue it in the second part of the course. And 86.9% wanted the practice exercises during the week to be evaluated. 100% wanted some kind of early evaluation.

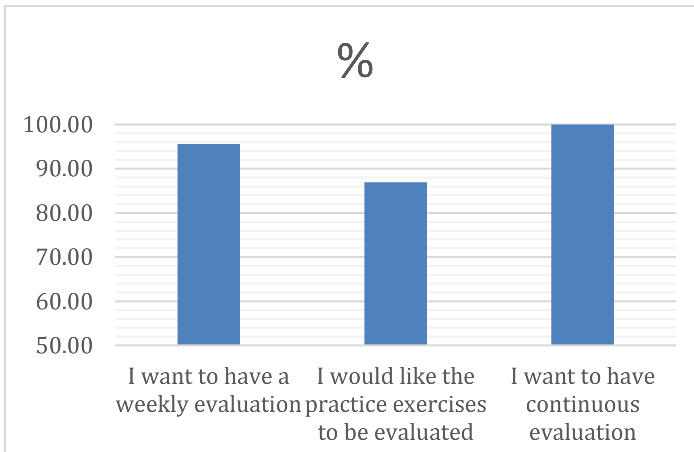
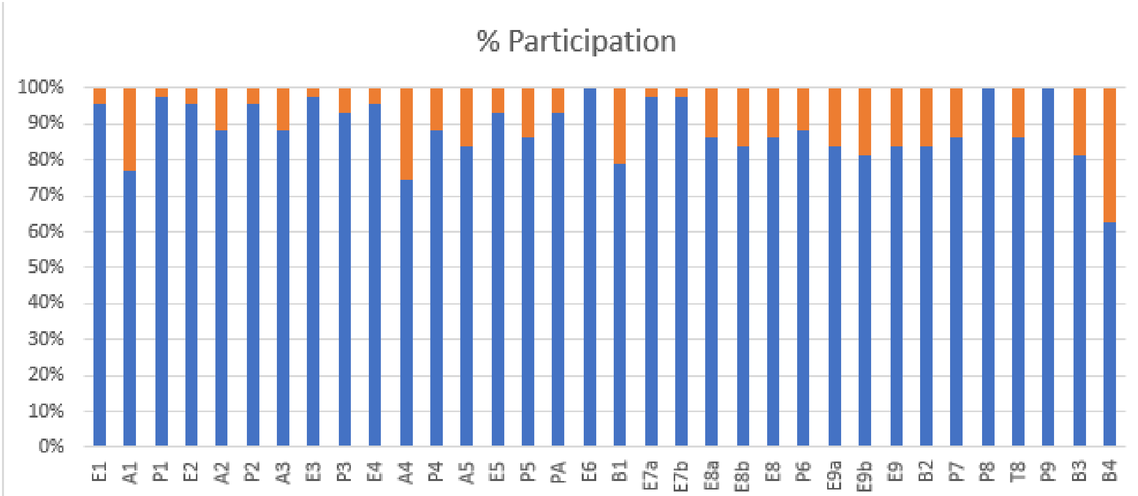


Figure 4. Student survey results

Regarding the learning process, it is observed that from the first week the students have an active attitude, which is shown in the results of the exercises they have as practice, the evaluated practices, and the participation in the subject's forum, where they ask questions about exercises of the subject and their classmates answer most of the times to them, if not the teachers and assistants of the subject answer them. In the survey, 73.9% of the students said that if there were no exercises evaluated, they would not practice weekly, compared to 26.1% who said they would practice anyway, so it can be concluded that the method especially favors those who need additional motivation for the work of the subject.

Figure 5 indicates the participation in the different activities of the continuous assessment (A: test of part A, B: test of part B, E: exercises in class and outside the classroom, P: weekly evaluated practice). It should be noted that the test exercises and evaluated practices were able to carry out only in the classroom. With the total data, all the students who took the final exam had taken more than half of the continuous assessment tests (out of 30 tests), 27.9% took 100% and 81.4% took more than 83% of the tests.



E: Homework exercises
A: Theory test part A
B: Theory test part B
P: Evaluated practice
PA: Partial test A

Figure 5. Percentage of students who participated in each continuous assessment activity (in blue)

In Figure 6 each row corresponds to all the exercises of a student and each red point to an exercise. So one row represents the performance of a student and a column how each student has answered an exercise. In the last two blocks the answers are produced alternatively in one block or the other corresponding to that they chose the anticipated or the normal evaluation. This table shows the general situation of the class.

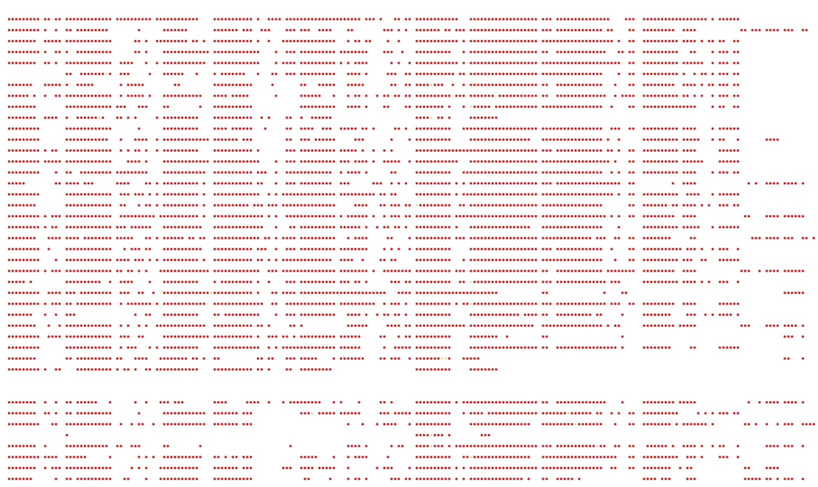


Figure 6. Overview of student exercises

As for the recommendations collected from students in the February 2018 survey, they request:

- More exercises. In fact, they have other exercises, but they prefer to have them in the automated evaluation platform, because if not, they do not even consider them as part of the subject, even though they are within the material part of the subject.

- They prefer videos made by the teacher; along with the 70 videos, 5 were external videos and they prefer that they be made by the teacher because they consider them more applied to the exercises they have to do.
- They prefer videos to documents, even though only 3 documents have been provided, they find them heavier.

CONCLUSIONS

The students' responses and their performance on the course show that continuous assessment is of interest to the students, which, although it requires continuous work, compensates them for having an early view of their status and distributing their workload.

In terms of student satisfaction, the point that might seem more debatable is the high number of tests assessed, but when asked for recommendations to improve in the subject, only one mentions it, along with the results of surveys that want to keep the tests assessed. This indicates that the continuous assessment, at least in the way it has been implemented in the subject, allows to integrate it in the subject's routine by evaluating all the activities both inside and outside the classroom.

Student performance has improved. It can be seen in the quality of the projects executed by the students and by the number of them performing the exercises in the final exam, although with the change with the anticipated evaluation it cannot currently be shown with a comparative numerical value.

Therefore, the change of evaluation system to a system of continuous assessment has had an effect on improving student participation and academic performance, so it can be inferred that training has improved. From the first day the students were working so they have been able to be more active during the course allowing the teacher to make the class more active and increase the interaction of the students among themselves and with the teacher.

The automatic correction tool favors the use of the incremental development model, a recommended programming method to which students are not usually used to, but which they adapt to because it is a simple system, and it is the one that guides their way of working.

Regarding the workload of the teacher, the first years has increased because they have to prepare the class exercises and evaluation in the tool, but once they are already worked is a basis that reduces considerably the time of preparation as it is to be modified gradually. The same happens with the theoretical videos of flipped learning. It should be noted that the correction time is zero.

In summary, the students' perception of the subject has improved considerably. They consider that they have learned more that the workload is well distributed and that their transversal skills have improved.

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TEACHING REFORM OF COMBINING INNOVATION ABILITY TRAINING WITH ENGINEERING EDUCATION

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ABSTRACT

In today's world, the cultivation of innovative and entrepreneurial talents has become a key factor affecting the country's core competitiveness. Innovation and entrepreneurship education is becoming a brand-new model pursued by higher education. However, most colleges and universities only work hard to continuously build and improve the innovation and entrepreneurship curriculum system. However, there is no good solution for how to integrate the cultivation of innovation and entrepreneurship ability with engineering education, and how to integrate the cultivation of innovation ability with industry needs. Faced with this problem, this article explores a set of teaching reform solutions that integrate innovative and entrepreneurial thinking and methods into professional practice courses. In the practice of professional courses, it collects real industry needs from school-enterprise cooperative enterprises, guides students' innovation direction and goals, and introduces TRIZ innovative methods to improve the level of innovative design. At the same time, the company's project implementation process and management methods are introduced into the practical training to improve the quality of the results in the design concept and system realization stage, and effectively enhance the students' innovation motivation and practical ability. Through the verification of the pilot course, this teaching reform method can effectively integrate innovative and entrepreneurial thinking methods with the majors learned, enhance the students' teamwork and knowledge integration and application capabilities, and can significantly improve the level of innovation in practical courses.

KEYWORDS

Cultivation of Innovative Ability, Innovation and Entrepreneurship, Engineering Education, CDIO, TRIZ Application, Standards: 1, 3, 4, 5, 7, 8

BACKGROUND

With the vigorous development of artificial intelligence and automation technology, industries with traditional repetitive labor are facing unprecedented challenges in terms of employment. Innovation and entrepreneurship have become an inevitable requirement for the sustainable development of human society. Throughout the world today, innovation and entrepreneurship education has become a brand-new model pursued by higher education. The national core competitiveness is increasingly manifested in the effective development, cultivation, allocation and regulation of human resources. The development and training of innovative and entrepreneurial talents has become the key to the country’s core competitiveness (Liu, 2011).

The report "Higher Education in the 21st Century: Outlook and Action World Declaration" published by UNESCO in 1998 pointed out that in addition to traditional academic and vocational education, young people in the 21st century should have a third education passport. That is, entrepreneurship education, it was at this conference that the concept of entrepreneurship education was formally put forward. The United States is the first country to carry out innovation and entrepreneurship education. It has incorporated entrepreneurship education into the national education system and covers the entire process from elementary school to graduate education. Entrepreneurship education courses have been generally offered in its colleges and universities (Tao, Yu, & Zhang, 2010). The British government also has the "Enterprise in Higher Education Initiative" (EHE) plan (Zhang, 2010), and the German government put forward the slogan "To make universities a melting pot of entrepreneurs" (Xia, 2014). Japan, Singapore, China and other regions in Asia are also actively promoting innovation and entrepreneurship education. It can be seen that innovation and entrepreneurship education has attracted widespread attention from all countries and regions in the world, and innovation and entrepreneurship education has become a new trend in international education and an important part of modern education, especially higher education.

ANALYSIS OF INNOVATION AND ENTREPRENEURSHIP EDUCATION

Paying attention to the current implementation of innovation and entrepreneurship education in China, there are still many unsatisfactory places in terms of educational effects and achievements. Colleges and universities that started relatively late inevitably have the problems of blindly following the trend, imperfect curriculum system, and vague curriculum content. Even colleges and universities that have implemented innovation and entrepreneurship education for a long time still have the problem of isolation between innovation and entrepreneurship education and professional education, and insufficient training of innovative practice capabilities within the profession.

First of all, the efforts made by the vast majority of colleges and universities in innovation and entrepreneurship education are continuous iteration and improvement in the construction of curriculum system and curriculum content. Although students can master the general innovative thinking and innovative methods, it is difficult to combine innovation practice with professional education and make effective innovative achievements in professional fields. The main reason is that the innovation and entrepreneurship curriculum system and the professional curriculum system are set independently of each other, the innovation and entrepreneurship ideas are not integrated into the professional education, the professional curriculum is still in accordance with the traditional teaching mode, the implementation process and steps of innovation methods are not fully considered in the curriculum content and teaching links, and the training of professional innovation and practice ability is lack.

Secondly, in the teaching of professional courses, the practical content is seriously out of touch with the development of the industry, the course cases are outdated. Therefore, the content of professional practice courses should keep pace with the times, and each round of teaching should update the latest technology and industry demand information into the classroom. Innovation and entrepreneurship training also requires innovative ideas based on the latest industry needs nowadays in order to make the practical content more innovative, practical and entrepreneurial.

In addition, if students only have good innovative ideas and cannot be realized, the ideas will lose their meaning and they will not be able to fully exercise their innovative practical ability. How to carry out teamwork in the implementation process and how to use efficient engineering processes and management methods to achieve high-quality completion of the project is also crucial. The operating mechanism of an enterprise is the best example in this regard, so introducing enterprise elements is the best way to integrate the classroom with society.

REFORM SOLUTION

Aiming at the problems of insufficient cultivation of innovation and practice ability, the isolation of innovation and entrepreneurship curriculum system from professional curriculum system, and the isolation of professional practice curriculum content from industry demand, this paper explores a set of teaching reform scheme of integrating innovation and entrepreneurship thinking and methods into professional practice curriculum. Through the point to area effect, improve the level of innovation and entrepreneurship practice education of the whole engineering specialty. The reform contents are as follows.

Integration of Innovative Methods and Practical Design Links

In order to solve the problem of lack of innovation and let innovation have a law to follow, innovative methods, namely TRIZ (Inventive Problem Solving Theory) innovation methods, are introduced in the practice links of professional courses. TRIZ is an innovative problem-solving theory invented by the former Soviet Union. After more than 60 years of development, a mature theory and method system for solving technical invention problems has been formed (Jing & Huan, 2005). According to the process requirements of TRIZ innovation theory, professional courses redesign the conception and design of CDIO, leaving room for the application of TRIZ method, and improving the innovation level of system conception and the rationality of the design.

Develop Practical Project Goals Based on Corporate Needs

In order to make practical innovation more practical and entrepreneurial potential, this article introduces corporate needs in the formulation of practical project goals, uses many professional-related corporate resources in the corporate practice base, and collects project requirements from companies, which can be products that companies are making. Either the technical content, or the business direction that the company plans to expand. After decomposing and filtering the actual needs of the enterprise, it is introduced into the practical teaching process of professional courses to ensure that the training of professional skills closely follows the needs and development of the industry.

Configure Corporate Mentors for Practical Projects to Improve Practical Ability

In the project implementation phase, in order to ensure the project quality, cost and time engineering requirements, in the classroom simulation of enterprise organization methods in project development and management. If conditions permit, enterprise mentors can be introduced from school enterprise cooperation enterprises to form a "double tutor" system. Enterprise tutors are mainly involved in the demand formulation, design review, achievement quality review and other stages of practical projects, aiming to introduce industry demand, enterprise development process, quality requirements and evaluation methods of achievements into the curriculum, so as to ensure the quality of practical achievements and ensure that students' ability training meets the requirements of enterprises.

IMPLEMENTATION OF REFORM PILOT CASES

Our school has been implementing innovation and entrepreneurship education since 2002, and has accumulated nearly 20 years of innovation and entrepreneurship education. The experience and existing problems in this area are very representative. This article takes the professional practice course of "Vehicle Information Technology Practice" as a pilot, and specifically implements the reform measures that integrate the cultivation of innovative practice ability and professional engineering practice ability, including the following aspects of implementation content.

Integrating TRIZ Innovation Method into Practice

According to the process of CDIO Engineering Education, the practice is generally divided into four stages, namely, conceive, design, implementation and operate. This process is more suitable for the process of engineering design and implementation in the case of clear development requirements. The most important thing that determines the innovation of a practical work is to establish the project objectives and analyze the solutions in the first two stages, and TRIZ method is best at solving the problems by using the completeness rule to find the solutions for specific scenarios (Chen, Jang, & Lu, 2015). This requires more innovation and design work in the Conceive stage and Design stage. In the course design, teachers should set aside corresponding class hours for TRIZ scheme deduction. The flow chart of TRIZ problem-solving process and CDIO process integration is shown in Figure 1.

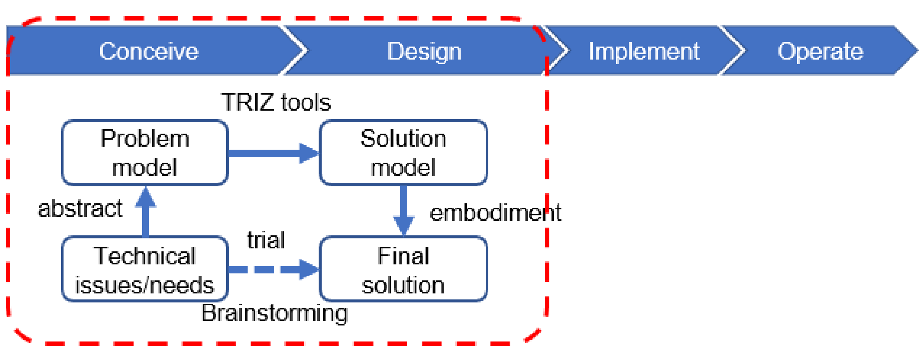

Figure 1. TRIZ Problem Solving Process and CDIO Process Integration Diagram

When using TRIZ for innovative design, the core process is to analyze the problems or requirements that need to be solved, abstract special problems into general TRIZ problems, and then apply TRIZ tools to find solutions based on the corresponding problem models. This process may require repeated program evaluation until the optimal solution is found (Guan & Zhu, 2015). The detailed process of using the TRIZ method is shown in Figure 2. In actual problem solving, the process of abstracting the essence of abstract problems and correctly applying TRIZ tools to obtain reference solutions is the focus of practical training.

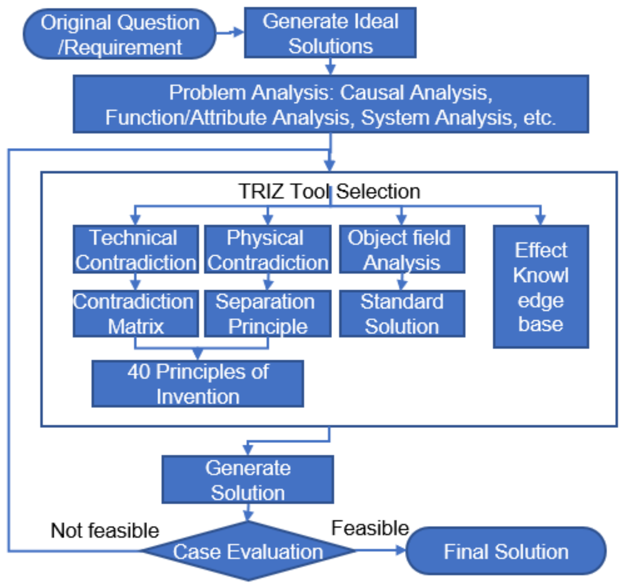

Figure 2. TRIZ Method Problem Solution Deduction Flow Chart

Here are two practical application examples in the course. The first example is that there is a function that allows the driver to sense the temperature outside the car. Students can easily think of using the temperature sensor to collect the temperature and display it on the electronic dashboard. But in fact, this is not a very good design, because a lot of status information has been densely displayed on the dashboard of the car. If it is displayed in the form of numbers, the driver needs to be very careful to see it clearly, which is very distracting to the driver. So, how can design be better? We try to use TRIZ Method to solve the problem below.
First of all, the contradiction in the problem is extracted. It is not difficult to find that there is such a pair of contradiction. For safety, the driver wants to get the temperature information in less time, but it leads to the loss of information because he can't see clearly. Therefore, we use this pair of contradictions to find the answer in the contradiction matrix, which can correspond to the No.25 waste of time and No.24 loss of information. No.25 is the optimization parameter and No.24 is the degradation parameter.

Two groups of parameters are queried in the contradiction matrix, and four reference solutions are obtained, which are No.24 intermediary, No.26 copy, No.28 replace mechanical system and No.32 change color from the 40 Principles of Invention. Please refer to Figure 3.

Finally, each group of solutions is brought into the application scenario of the problem to find the appropriate solution. In this case, the best solution is No.32 change the color, that is to change the color of the digital dashboard screen according to the temperature. As long as the driver can sense the temperature change according to the color change of the dashboard. But the rest solutions are not suitable.

Another example is the use of face recognition technology to confirm the driver's identity, in order to automatically adjust the seat position, air conditioning temperature and other parameters. In the scheme design, students encounter such a problem, if the driver has not been on the car, the face recognition function will continue to recognize, because the face recognition algorithm consumes processor performance, which brings the problem of performance waste. In the face of this software problem, we find the contradiction between improving No.38 degree of automation and No.22 degree of energy waste, and finally find the method of introducing feedback to solve the problem by using the contradiction matrix of TRIZ.

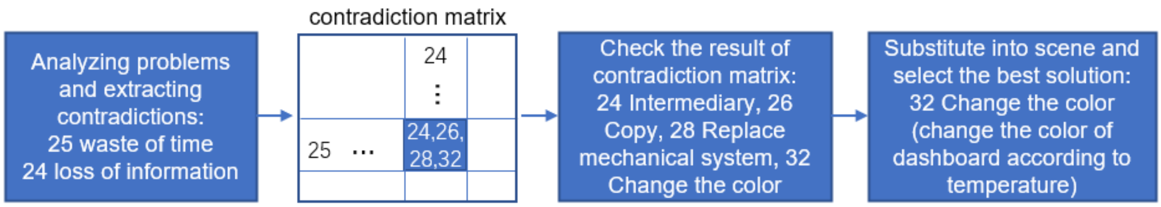

Figure 3. Application process of TRIZ Method in temperature case

The TRIZ method is certainly an advanced method in guiding innovative thinking. However, if specific application scenarios and specific requirements are not provided, it is difficult to produce valuable innovative works out of thin air. Therefore, in order to make practical works more scene-oriented, it is necessary to combine the following second content to establish project goals.

Collect Real Needs of Enterprises and Guide the Direction of Innovation Based on The Framework of School Enterprise Cooperation

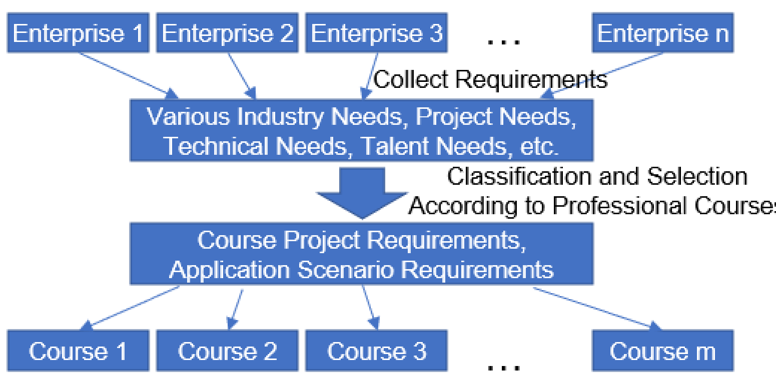

Figure 4. Flow Chart of Project Requirements for Courses Collecting from Enterprises

The topic selection of practice project is the key to guide innovation. If the teacher specifies the topic, it will focus on the project design and implementation, which limits the students' innovative thinking. On the other hand, if students are allowed to choose topics freely, they will go to the other extreme. Either the goals set are too ambitious to achieve, or they have no practical value due to lack of industry background knowledge.

In this project, the topic selection method of practice project is reformed, and the enterprise resources related to many majors in the enterprise practice base are utilized. According to the process of Figure 4, the curriculum project requirements are collected and refined. First of all, collect project demand, industry demand, technology demand and talent demand from the enterprise, which can be the product or technology content that the enterprise is working on, or the business direction that the enterprise plans to expand. Then the teachers of professional courses will filter and screen the collected demands, and classify, summarize and sort them according to the course contents, so as to form the project demands suitable for the course. In this way, it is meaningful for students to use TRIZ to determine the practical design objectives. Such a guided innovation will help students' achievements not only meet the professional requirements of the course, but also have value in the application of the industry. As shown in Table 1, it is the enterprise requirements collected and sorted out in the course practice of "vehicle information technology practice".

Table 1. Demands of Enterprises in the Direction of Automotive Electronics

category	requirements content
Business requirements	Mobile app and vehicle machine interconnection, people find the car, car track record, dynamic electronic instrument panel, intelligent driving assistance, driving safety detection, Car perception of people, human machine interaction, other innovative functions
Technical requirements	Solid C language foundation, Linux system, data structure, Android development, Qt development, basic hardware knowledge, problem solving ability
Management requirements	Understand the development process, have documentation capabilities, quality and cost awareness
Cooperative communication	Good communication, division of labor and cooperation, responsibility, and strict delivery

In terms of implementation procedures, the program can take advantage of the existing school-enterprise cooperation framework to collect corporate employment needs every year and issue a demand-collection questionnaire to the company to obtain corporate demand information. The formation of annual operating regulations in this way can ensure that the school grasps the latest corporate demand trends, and guide the teaching goals of the courses accordingly. Naturally, the teaching content of our school can keep up with the pace of the times and always maintain fresh vitality and competitiveness.

For the enterprise, the new direction that the enterprise wants to try to develop is combined with the school through the school-enterprise joint method, and the student's innovation results are fed back to the enterprise, which has great mutual win value for the enterprise's selection of talents and product trials.

Set Up Enterprise tutor to Introduce Enterprise Processes and Standards into Classroom Practice Projects

Our school has accumulated a lot of school enterprise cooperation resources in enterprise practice base and scientific research cooperation. In this case, we invite experienced engineers from the school enterprise cooperation enterprises as enterprise tutors, and form a double tutor system with school professional teachers. The technical backbone of an enterprise or the person in charge of human resource recruitment mainly participate in the demand formulation of practical projects, the evaluation of intermediate achievements, and the evaluation of project achievements, as shown in Figure 5. From the perspective of the enterprise, the enterprise tutor reviews the students' achievements, points out the problems, introduces the practices of the enterprise, and puts forward suggestions for improvement.

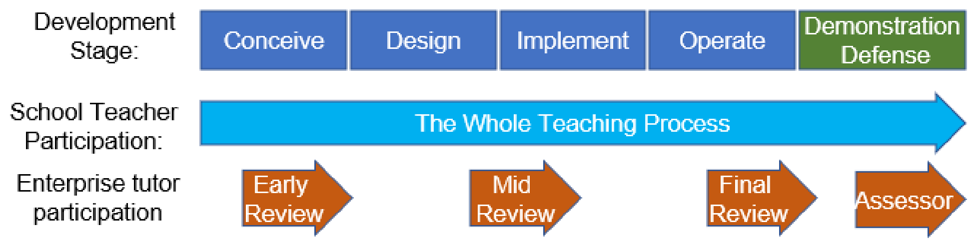

Figure 5. Schematic Diagram of Corporate Tutors Participating in Courses

Through the enterprise tutor, we can further obtain the industry demand of the enterprise's field, and set up the evaluation link for the enterprise tutor to participate in in the middle of the course or the final results display link, so that students can understand the requirements, development process and evaluation standards of the enterprise, which is conducive to students to understand more information of the enterprise before graduation, and can stimulate students to learn Students learning enthusiasm, can also get more relevant industry background knowledge.

For the employers of enterprises, they can understand the learning content of students and pay attention to the talents meeting the needs of enterprises in advance, and also introduce the enterprise's talent training content to the school teaching stage in advance, which greatly shortens the training time from graduates to enterprise employees, and reduces the enterprise's talent training cycle and cost.

Combining with the enterprise development process to refine the course project process and clarify the requirements of the achievements in each stage, students can learn more process principles and the correct production methods of the achievements in each stage in practice. So that they can complete the development of the achievements according to higher quality standards. On the other hand, they can cultivate the habit of completing the project according to the development process and methods. Table 2 is the corresponding table of development stages and achievements of embedded software development projects in the course practice.

Table 2. Development Stage and Result Material Correspondence Table

Stage	Development content	Achievements
Conception design	Demand survey and feasibility analysis Do outline design and review Develop project plan	Requirements specification book Summary design book Project plan
Detailed design	Detailed design: UI design, module design, process design Detailed design review Test case design and review	Detailed design book Test pattern book Issue management table
Coding implementation	Coding and debugging Code review Combination test	Source code Issue management table
System testing	System testing and debug System test review Result collation and data preparation	Bug management table Test result book Software publishing reports and materials

REFORM EFFECT AND SIGNIFICANCE

The implementation of this curriculum reform fully integrates the cultivation of College Students' innovative practice ability with the training of professional practice ability, and has achieved good reform effect. If the enterprise's evaluation criteria for talents are summarized into five aspects, with a full score of 10, the comparison results shown in Figure 6 can be obtained.

(1) Basic knowledge: the focus of this reform program is to improve the ability of innovation and practice, so there is no obvious effect on the improvement of basic knowledge.

(2) Problem solving: due to the introduction of enterprise management methods, the project division is more clear, and TRIZ method is used to assist analysis, which promotes students' ability to analyze and solve problems independently, from an average of 7 points to 8 points.

(3) Management process: there is almost no project management in the original course, so the introduction of enterprise project management and development process has played a significant improvement effect on the orderly promotion of the project and risk prevention. Although students cannot fully understand the necessity of some process settings, they have also achieved a good score from 5 to 7.5.

(4) Scheme design: due to the introduction of TRIZ analysis method and project development process, as well as increasing the proportion of class hours in the design process, the rationality and standardization of scheme design have been greatly improved, from 7.5 to 9.

(5) In terms of innovation and creativity: the introduction of TRIZ Method and the increase of the proportion of class hours in the conception stage significantly improved the innovation effect, from 6 points to 8.5 points.

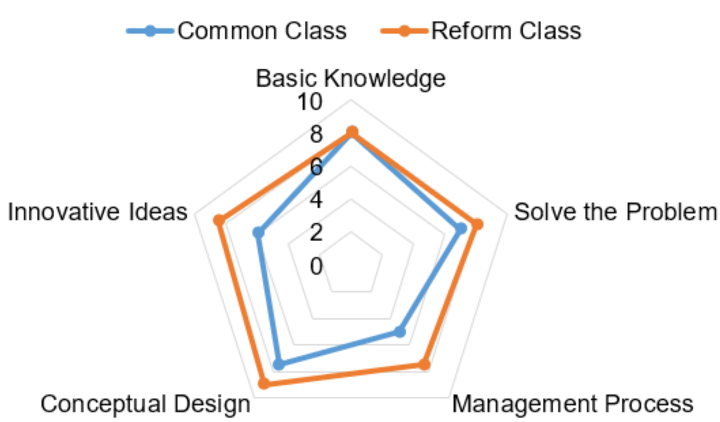

Figure 6. Radar Chart of Teaching Effect Contrast

The starting point of this reform program is in line with the concept of Outcomes-based Education (OBE), and it is oriented to the needs of enterprise talents and society for innovative and entrepreneurial talents. It effectively solves the problem of separation between innovation and entrepreneurship education and professional education.

(1) In the aspect of integrating theory with practice, this paper puts forward the innovation of practical methods, and integrates TRIZ method based on theory teaching into professional practical courses.

(2) In terms of the use of school enterprise cooperation resources, this paper puts forward the innovation of win-win utilization of resources, uses the existing school enterprise communication channels to collect enterprise needs, provides information channels for guiding curriculum practice objectives, shares curriculum innovation achievements with enterprises, and also provides innovative ideas and inspiration for enterprise product innovation.

(3) In the practical guidance mode, the innovation of "double tutor" system is put forward, which can invite enterprise personnel to participate in the practice, improve the quality of practice results, promote mutual understanding between school and enterprise, and form a virtuous circle of school enterprise cooperation.

CONCLUSION

In the cultivation of innovation and practice ability, the reform measures enable students to experience the whole process from creative conception to concrete realization by means of engineering technology. In the short term, it can improve students' innovation and practice ability and the innovation level of practical courses. In the long run, from quantitative change to qualitative change, the improvement of innovation ability will inevitably lead to excellent entrepreneurial achievements, so as to promote more employment and relieve the social employment pressure. Finally, the real purpose of education serving the society and creating students' value is achieved.

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BIOGRAPHICAL INFORMATION

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DATA ANALYTICS OF STUDENTS CONTINUOUS ASSESSMENT ACTIVITY DATA

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ABSTRACT

Codex is a web-based tool for the online edition of theoretical and practical teaching content, and for assessment of STEM subjects. It has been developed at TECNUN, the Engineering School of the University of Navarra. The Codex application helps teachers to promote active learning (Standard 8) and continuous assessment (Standard 11) without increasing the teacher's workload. Codex is being implemented in the classrooms, which opens another door for the improvement of the learning experience. Codex stores a significant amount of data from each student, which can be used both by the teacher to adapt his or her teaching method and by the student to see what his or her strengths and weaknesses are and be counseled personally. All of this is supported by up-to-date data. The aim of this project is to apply different Data Analytics and Machine Learning methods to the obtained data in the application from a subject called Digital Technology, in order to obtain a prediction of students' grades and performance at each moment of the course, based on his/her behavior and that of previous years' students. This allows the teachers to know information related to performance of their class, and the students, to see towards what result they are heading.

KEYWORDS

Learning analytics, continuous assessment, automated assessment, Standards: 8, 11

INTRODUCTION

The important progress in information technologies and the growth of their use in different areas of life allows the automated generation and capture of large amounts of data automatically. From the analysis of this enormous volume of data, very valuable information and knowledge can be extracted, future events can be predicted (and therefore prevented) and existing processes and tools can be optimized.

Data analytics benefits in education

In the last decades the use of ICT has also been introduced in education, not only for online education but also as a support to face-to-face teaching. The analysis of educational data can provide new insights about the educational process and allows improving the teaching-learning process and more specifically the performance of students and teachers (Larruson & White, 2014). The areas in which it is applied can be at the level of a student, a class or even one or more institutions.

Research in this area has acquired relevance in recent years, giving rise to Educational Data Mining (EMD) and Learning Analytics (LA) (Romero & Ventura, 2020).

Each of the data analysis methods applied to education helps to obtain different types of information (Bogarín, Cerezo, & Romero, 2018). One of the first applications of data analysis is the ability to predict future outcomes. Applied to the field of education, one can predict the grades or performance of students based on the results of previous years or the same student throughout the course.

These predictions provide information that helps measure the quality of the teaching-learning process. At the same time, different actors in the educational process can take advantage of this information and make changes with the intention of improving learning outcomes. For example, knowing the data from their classes, teachers can modify both the way of teaching and the way of grading their subject. In the case of the students, they can modify their attitude or their study method to face the subject.

Data analytics drawbacks in education

Despite the benefits that LA can bring to the improvement of the teaching-learning process, there are different risks. In a classroom setting, results could be prioritized over student learning, resulting in a surface-learning (Jordan, 2009). Instead, the information shown to the students could contribute to their lack of motivation, and therefore, to their abandonment of interest in the subject. It is the role of teachers to make sure that the use of LA is always for the benefit of the students and to avoid this kind of situations (Arnold & Pistilli, 2012), filtering the information and being aware that some data are not considered in the prediction, such as a student's personality.

Data analytics barriers in education

The difficulties we may encounter when applying data analysis in education focus on two aspects: data collection and data standardization. In order to collect the data, it is necessary to use a tool that stores the students' grades. However, it is also highly recommended that the tool not only stores the grades, but also corrects and evaluates the students, and assigns the grades. This saves the teacher a lot of time. However, the data collected in education is very variable due to several factors. An example is often that students do not take a test, and therefore are not assigned a grade. There are also problems when data from other academic courses are required, since it is normal that the exercises used to evaluate vary every year.

MOTIVATION

Our thesis is that continuous assessment can be considered an enhancer of student learning if, through an adequate and easy-to-use LA tool, teachers and students can obtain valuable information extracted from the data provided by the different assessment actions. We choose LA as the next step in the development of the assessment tool, as a research line with a huge growth in recent years and with great potential to improve education. We emphasize the easy-to-use aspect of the tool, since the existing tools are oriented to experts.

To facilitate continuous assessment, an automated evaluation tool has been developed and is already being used in several subjects of our engineering degrees (cf. Serrano *et al.,* 2018). In another paper submitted to 17th International CDIO Conference (Nicolás Serrano, Blanco, Calderón, Gutiérrez, & Serrano, 2021) the continuous assessment method implemented in a second-year programming subject is described.

The study is the first step in the current development of a Learning Analytics assistant that, fed with the continuous assessment data, facilitates and improves the learning process: providing information on the situation of the class and of each student and proposing recommendations. Once the LA tool is available, we will proceed to research on the impact of its use in improving learning.

MODEL DEVELOPMENT

Our goal is to conduct a study that allow us to know if it is possible to predict the results of students in a subject at our university. This prediction should be based on the data that has been collected on the subject in the past and during the course. We clarify that each teacher could use this method if the teaching topic is evaluated quantitatively. At the organizational level, it is recommended to apply the same evaluation to the whole class. In this case, the organization of the data for each student will be the same, facilitating the development of an LA model.

Data preprocessing

As mentioned in the previous section, data collection is the first difficulty one encounters in data analysis. Therefore, we have decided that the chosen subject is Digital Technology (DT), a subject in which students learn to program in the Java language. The goal of the course is that the students use the knowledge they have acquired during the course to solve real problems. For example, to design and program a simple web application. The reason for choosing this subject is that a system of continuous assessment has been introduced in previous years (Nicolas Serrano et al., 2018). In this system the student had to take tests and exercises every week, which contributes to the fact that the amount of data is significantly higher than in other subjects. The students get points with the tests and exercises, which take part in the final grade among exams and a final project.

In addition, these activities were carried out through Codex, a platform with different online teaching resources. The platform allows for automatic grading of activities and storage of student grades. Another advantage of the platform is that the activities, called items in the platform, usually follow the same structure from year to year as they are copied and modified. As each copied item has the ID from the original one, we are able to link those items in the model. To start with the analysis, the only step required is to import the data from the database to be able to use it in our program.

At this point it should be clarified that the questions and exercises that appear on the platform are called items. And the items are grouped in notebooks, which are the ones presented to the students. Related to the analyzed subject, the platform had in the moment 216 items, grouped into 46 notebooks. There are two kinds of items used in the chosen subject. The first kind of items are tests where the student must choose the correct statement. These items are used to evaluate the theory of the subject. The second kind of items consist of programming problems and the students must introduce their code. Each student's answer is recorded on the platform, and the data obtained for each answer includes: the answer's ID, the student's ID, the item's ID, the grade obtained, the timestamp of the answer, and the maximum grade that can be obtained. A sample of this data is shown in Table 1. Before using the data, we decided to anonymize the student's ID so the information cannot be related to any real student.

Table 1. Original format of dataset.

```
          USERID  ITEMID  MARK              ANSWERDATE  MAXGRADE
0     1058277809    4214   0.0 2020-01-24 15:51:53.373       1.0
1     1058277809    4214   0.0 2020-01-29 22:08:48.055       1.0
2     1058277809    4498   1.0 2020-01-30 17:35:54.352       1.0
3     1058277809    4499   0.0 2020-01-24 16:22:35.452       NaN
4     1098327170    4499   0.0 2020-01-24 17:40:56.535       NaN
...          ...     ...   ...                     ...       ...
7416  1260649978    5386   0.0 2020-06-02 17:46:34.055      14.0
7417  1203634691    5383  12.0 2020-06-02 17:05:48.319      12.0
7418  1203634691    5384   0.0 2020-06-02 17:41:02.427      12.0
7419  1203634691    5385  12.0 2020-06-02 17:19:37.827      12.0
7420  1203634691    5386   0.0 2020-06-02 17:37:51.224      14.0

[7421 rows x 5 columns]
```

To begin with, we need to export the data from the database into our python program as a new dataset. We are getting answers from January to September 2020, as the database may contain information which corresponds to a new course. Also, we are only getting the last students' answer for each item. This last filter is applied because the student can give multiple answers for the same item if the teacher allows it.

In this research we decided to use only data from the grades, as it is considered as the most significant to predict the final grade (Arnold & Pistilli, 2012). Then, the input variables to our model are the item grades and the target variables are the final grades, so our desired structure is the one shown in Table 2. In the table, we have an initial column with the student IDs, several columns with the student grades (one for each item), and a final column with the final grade, computed with the item grades. Then, each row shows us all the required data from each student.

Table 2. Desired format of dataset.

Student ID	Item 1	Item 2	...	Item m	Final grade
Student 1	0.2	0.5	...	1	0.8
...	...	...	...	...	...
Student n	1	0.7	...	0.8	0.75

The next step is the standardization of the grades. As it was mentioned earlier, the variability of educational data forces us to adapt the data before applying any data analytics method. So, we normalize the grades into a 0-1 range, as they have different formats for each item. This helps optimize the algorithm's performance. We do so by dividing each grade by the maximum grade for that item. If it is missing for an item, we find the maximum grade achieved by any student and use it as the maximum grade.

However, there are a few more changes to be done which improve the algorithm’s performance. On the one hand, we remove the items that do not give us any information. These are the ones with a 0.0 grading. Either they were items with only a theoretical explanation (without evaluation), or they were asked not to be answered by the professor. On the other hand, we have missing values that are stored as NaN values, which represent the questions with no answer. Thus, we convert all the NaN values to a 0.0 mark. An example of the final result is shown in Table 3.

Table 3. Final dataset.

	USERID	4214	4499	4498	4217	4500	4215	4218	4252	4219	...	\
0	1001878881	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.00	...	
1	1008562537	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	0.50	...	
2	1009074790	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.00	...	
3	1009358503	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	0.75	...	
4	1010498129	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.00	...	
5	1011762717	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.00	...	
6	1034515793	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.00	...	
7	1039454863	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.00	...	
8	1042775892	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	0.00	...	
9	1059658959	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	0.75	...	
10	1062206845	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.00	...	
11	1069422119	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.00	...	
12	1077598052	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.00	...	
13	1083182240	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.00	...	
14	1087192798	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.00	...	
15	1098327170	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	...	

Now the data has the correct shape, and we can easily visualize a student’s grades progress throughout the year. Figure 1 shows the data from a random student. In the figure, the x axis indicates the items ordered in time and the y axis represent the normalized grade. Then, blue crosses represent each item’s grade, the red line is the final grade, and the green curve represents an approximation of the accumulated grade or the amount of the final grade obtained with the answered items.

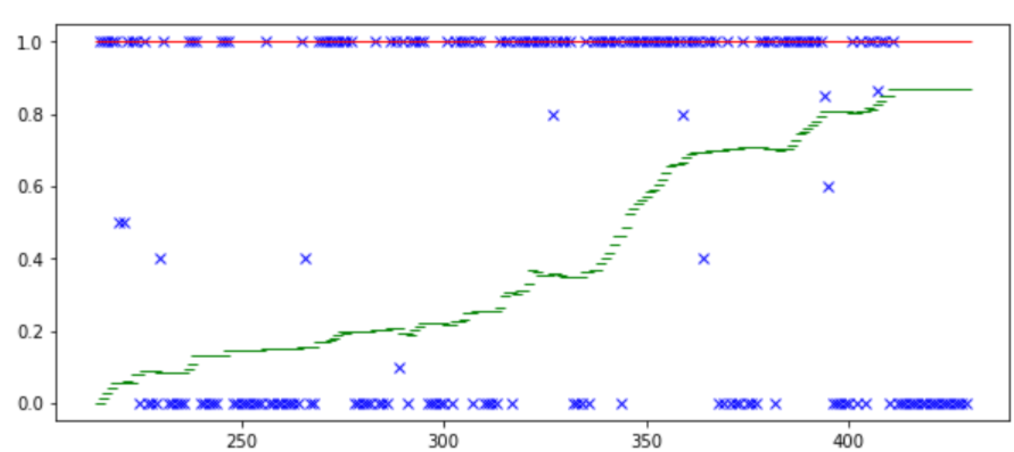

Figure 1. Random student's progress.

Model fitting

The next step is to train the linear regression model with scikit-learn's LinearRegression model (Raschka & Mirjalili, 2017). The multiple linear regression model takes m input variables, $x_m\ \forall m \in (0,1)$, and tries to find the coefficients, $w_m\ \forall m \in (0,1)$, to produce the outcome y that best fits the actual solution:

$$y = w_0 x_0 + w_1 x_1 + \cdots + w_m x_m = \sum_{i=0}^{m} w_i x_i = w^T x$$

Then, we need to split our data into a training and test dataset. Using scikit-learn's `train_test_split` method, we define the percentage of the samples that are going to make it to the test dataset. We are going to train the model to predict the final grade based on 150 items completed, out of all the 216 items that compose the course. Once both training and test datasets are created. We get the slope and intercept values of the fitted model by calling the `coef_` and `intercept_` methods from the LinearRegression object. The slope is defined by the coefficients of the model, and the intercept refers to the independent term. As we are working on a high-dimensional feature space, it is not really helpful to visualize the solution.

Using the trained model with linear regression, we predict the final grades and compare them with the ones obtained by students. The results are shown in Figure 2 for a group of students. In the figure, x axis represents the students, and the y axis the grade between 0 and 1. Blue crosses represent the actual grades, whereas red crosses are the predicted ones. Considering a figure similar to Figure 1 for any student, the maximum value of the green curve would be represented in this figure as a red cross.

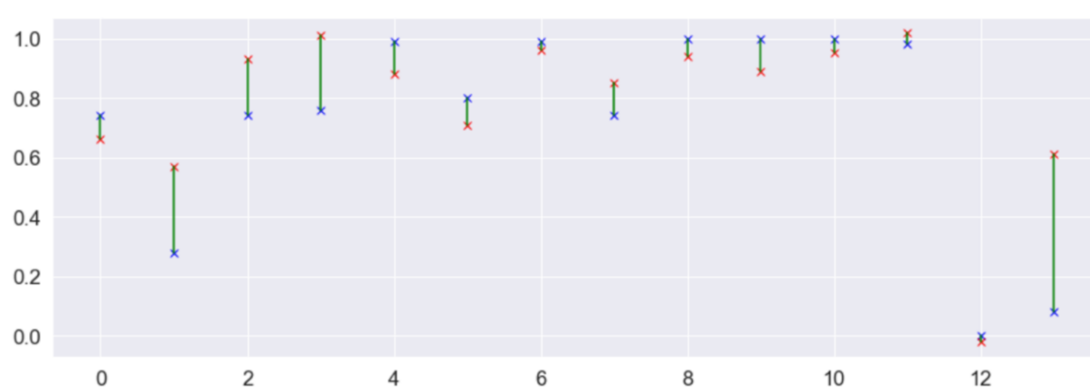

Figure 2. Comparison of actual and predicted final grades.

Figure 2 Comparison of Figure 2 shows a general good accuracy for most of the students, but it fails to predict correctly two of those students (the second and last one) by a large error. Following this problem, we checked to see if those two students had anything in common between them and whether they differed much from the rest of the students. Comparing the plot from Figure 1 and the ones from both "outliers" progress, shown in Figure 3 and Figure 3, we discovered that both the students with a greater error at the prediction are students who dropped the course before answering 150 items. It is understandable that this situation causes the error from Figure 2, with both students having a much higher predicted grade than the achieved one. This is because the model is only trained with the first 150 items, where the students had a better performance than the one in the second half of the course. As the model does not know that, it predicts a much higher value.

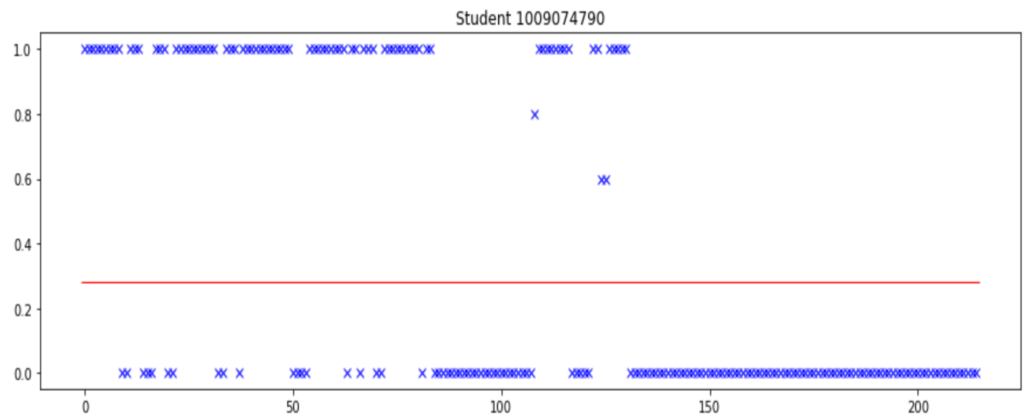

Figure 3. Course progress of the first outlier.

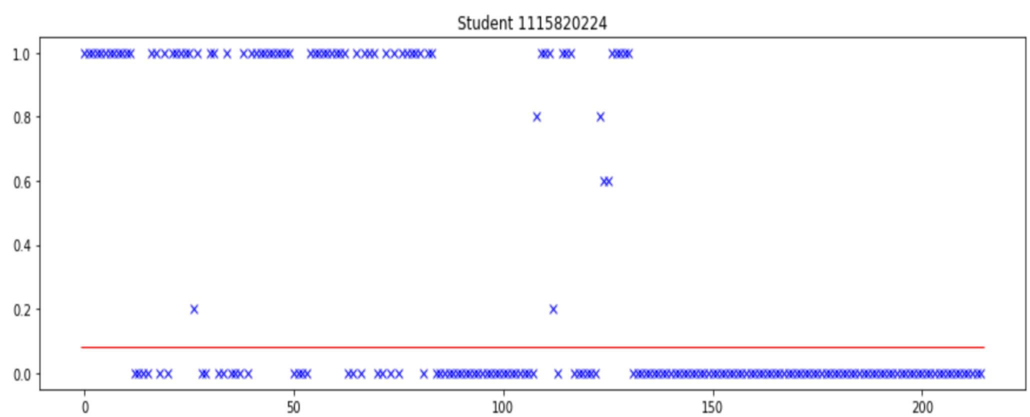

Figure 4. Course progress of the second outlier.

Finding a way to target which students are going to drop is a matter that needs to be assessed properly to prevent it. In addition, it is important as these cases must be leaved out of the training dataset so they do not affect the model's accuracy. A comparison of the accuracy of the model with and without outliers, with a test set of 20% of the items, is shown in Table 4. Despite that the mean squared error is greater without outliers, the R2 score increases significantly, which means that the prediction is more reliable. At the moment, we tackle this problem by manually selecting those students who are outliers and leaving them out of our data frame.

Table 4. Accuracy comparison of the model with and without outliers.

	With outliers	Without outliers
Explained variance	0.44	0.78
Max error (grade pt)	0.27	0.40
Mean absolute error (grade pt)	0.13	0.12
Mean squared error (grade pt^2)	0.02	0.03
Median absolute error (grade pt)	0.11	0.06
R2 score	0.43	0.71

RESULTS AND DISCUSSION

Using the model that has been developed and described in the previous section, we have made predictions by simulating that students are in different moments of the course. This is equivalent to having stored a different number of answered items from students. We have made predictions using 25%, 50% and 75% of the available items. A comparison table is shown in Table 5. The table shows the accuracy scores of the model for the three cases. As Table 5 shows, the scores improve when we use half of the available items compared to only using 25% and it slightly gets worse using 75%. This is a common behavior in data analysis, as the prediction improves as we include more data, which explains the difference between using 25% and 50%. The difference between using 50% and 75% is more difficult to explain. Our guess is overfitting, as the added information fits the result in the model and it does not have into account possible variations at the end of the course.

Table 5. Accuracy scores of the model for 25%, 50% and 75% of the available items.

	25%	50%	75%
Explained variance	0.56	0.78	0.74
Max error (grade pt)	0.28	0.37	0.40
Mean absolute error (grade pt)	0.16	0.09	0.11
Mean squared error (grade pt^2)	0.03	0.02	0.02
Median absolute error (grade pt)	0.19	0.06	0.05
R2 score	0.55	0.76	0.68

CONCLUSIONS

The results have shown us that it is possible to predict a student's final grade in the subject quite accurately. This phenomenon occurs even if only a quarter of the course has been graded. The data show us that the prediction improves with respect to the progress of the course, since more data is obtained from each student. It has also been found that those cases in which a good prediction has not been achieved are those in which the student has decided to leave the subject. In the future, a way to automatically detect these special cases could be investigated in order to prevent them.

Considering the obtained model, it was discovered that some items have a negative coefficient to compute the prediction. Therefore, they probably do not evaluate correctly the knowledge of the students. For example, a good grade in one of those items means that the predicted final grade for the student will be lower.

These conclusions encourage us to show this information to teachers and students during the next course in the platform. Then, as it is previously mentioned, we will proceed to research on the impact to enhance the model, considering that the results may vary. For example, the students may modify their performance and attitude when they know this information. If this situation occurs, it is possible to calculate if the additional information has contributed to improve the students' performance.

Finally, we pretend to apply the same assessment method in other subjects. Then, it would possible to study if the predictions of the final grades have similar accuracy.

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INTRODUCTION TO INDUSTRIAL DESIGN AND PRODUCT CASE STUDIES

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ABSTRACT

This paper describes the practical elements included in the first term of a second-year engineering module which was developed in alignment with CDIO standards. The students were assigned into teams based on their course of study (i.e. electronics, biomedical, and sports engineering). Each team would be free to choose, research, and evaluate three products with some relevance to their field. Aspects such as technology, regulations and user reviews would have to be considered within the analysis. The scientific principles involved in the products would have to be explained in reasonable depth and aspects such as product end-of-life management (sustainability) also mentioned. Multiple sources would have to be used such as scientific articles, product specifications, regulations, and online reviews. The students would have to use available resources without necessarily having the actual physical product at hand. Once the teams had gained insight on the products they would have to either choose one of the products to improve, or decide to design a new product, (relevant to their discipline). The teams would have to produce a report and a demonstrator of their designs by the end of term. The demonstrator would have to be a physical representation with some functionality that can effectively communicate the proposed concept. The students were expected to use the tools and experience gained during previous and prerequisite modules, for designing and prototyping. The report was also expected to contain references to the indicative reading. The module would be an opportunity to build upon previous knowledge obtained through both, core and specialized modules. Additionally, a research element was included both in terms of the students looking into the cutting-edge technologies of their subject but also in trying to push those boundaries. This study aims at describing the module rationale, and reflecting upon inclusivity, and pedagogical effectiveness.

KEYWORDS

Group projects, innovation, industrial design, Standards: 1, 2, 3, 5, 7, 8

INTRODUCTION

In 2017 a new engineering department was established at Nottingham Trent University (NTU). The first cohort included three courses i.e. biomedical, electronic and sport engineering. The department has since been developing to foster an inclusive ethos and a modern approach that corresponds to the current professional needs and in alignment to CDIO standards. In that context the first term of a second-year module was developed. The term grade would account for 50% of the module grade. The module was named 'Industrial design and product case studies' and was taken by all engineering courses (35 students in the first cohort). The cohort included both native and international students of various educational backgrounds (e.g. international, more technically or theoretically focused) and with a multitude of talents, areas for improvement and strengths. This study aims at describing the module design rationale, and reflecting upon the design impact in inclusivity, and pedagogical effectiveness.

The module learning outcomes included:

- Source industry relevant information, some from the scientific literature, to inform the design and manufacture of engineering products/systems.
- Review and evaluate information related to end-user needs, materials and component properties, industry standards and methods of fabrication, including knowledge of industrial manufacturing processes, economic viability and environmental concerns.
- Formulate and manufacture engineering solutions to overcome discipline specific engineering problems using standard engineering solutions.
- Utilize digital methods in the design and fabrication of engineering products.

The aim was for the module to fulfill the desired learning outcomes, in a way that would be representative of a working environment, cultivate creativity, and enable all students to utilize and hone their strengths while developing in new areas. This would also adhere to the concept of constructive alignment as the purpose of each task would be clear to the students (Biggs, 2011). As the module name implies the students would have to explore case studies of industrial design. Due to the department being new, that was the first time that the specific module would run at NTU. It is not uncommon in such modules to be taught in a traditional lecture manner whereby the educator delivers knowledge through a lecture format and then an exam is constructed to test the retention and understanding of that information. Case studies might have been the topic of lectures perhaps covering one example per session. Nevertheless, the purely passive demonstration model is not necessarily the most effective in sciences that include practical elements. For example, Crouch et al. (2004) found that physics demonstrations to pre-medical students had no significant effect on correct answers.

In 1996 MIT was evaluating its curriculum and in collaboration with Boeing constructed a list of desirable attributes of engineering graduates. This to some extent contradicted the weight that some schools would assign to the 'soft skills' in comparison to that of industry (McMasters & Matsch, 1996) With that in mind, the module was designed with an approach of guided and supervised self-learning based in lab sessions rather than lectures, and closer to a Humboltian model of academic education. The main bulk of contact time would be spent working in teams and in the laboratory with the support of 3 lecturers and technical staff.

Prince (2004) suggested that active learning is an effective method and in addition to the team element (Johnson & Johnson, 2008) may enhance meaning extraction. Additionally, it is argued that including social interaction can be an effective way of learning (Ashwin et al., 2015). A significant aspect would also be the contribution of multiple members of staff as Thomas et al. (2015) emphasise the importance of staff support and environment to facilitate effective self-learning. The effectiveness of the method would be evaluated by student feedback through anonymized questionnaire forms, student grades, moderation by colleagues, and fellow staff feedback that would be invited to participate at a specific phase of the module.

Below the module design is described in more detail and considerations regarding student achievement are discussed. Student achievement is addressed in both the specific sense of grades but also in the general sense of being equipped with a range of skills that are conducive to professional success. The variety in terms of student backgrounds, talents and skills might correspond to that different students have different needs in terms of areas they need to develop. The module, would provide with a sufficient variety of tasks so that students could both shine through their talents and also develop needed skills.

MODULE DESCRIPTION

The students were assigned into teams based on their course of study (i.e., electronics, biomedical, and sports engineering). Having taught the cohort in the previous year and considering its small size, I already knew the students. Some consideration was taken in forming the teams based on general student performance and engagement during the previous year. Although the performance of previous years is not necessarily deterministic of future performance, the aim was to try and ensure a reasonable balance between teams. Each team would be free to choose, research, and evaluate three products with some relevance to their field. Aspects such as technology, regulations and user reviews would have to be considered within the analysis. The scientific principles involved in the products would have to be explained in reasonable depth and aspects such as product end-of-life management (sustainability) also mentioned. Multiple sources would have to be used such as scientific articles, product specifications, regulations and online reviews. The students would have to use available resources without necessarily having the actual physical product at hand.

Once the teams had gained insight on the products they would have to either choose one of the products to improve, in at least one aspect (e.g. function, cost, sustainability, manufacturing), or decide to fully design a product of their own, (relevant to their discipline). The teams would have to produce a report (including CAD design in Fusion) and a physical demonstrator based on their design by the end of term. The demonstrator would have to be a physical representation with some functionality that could effectively communicate the proposed concept. A full functioning prototype would be preferable and appreciated, however it might not have been feasible given the available time. The students were expected to use the tools and experience gained during previous and prerequisite modules, for designing and prototyping. The report was also expected to contain references to the indicative reading. The module would be an opportunity to build upon previous knowledge obtained through both, core and specialized modules (Fry et al., 2008). Additionally, a research element was included both in terms of the students looking into the cutting-edge technologies of their subject but also in trying to push those boundaries (Barnett, 2005).

The length of the analysis part of the report was restricted to 3 pages per product, however equations, figures and appendices were excluded from that allowance. The aim was to force the students into evaluating and distilling the vast amount of information about the products so that to reflect and include only the relevant and important parts.

The projects were structured in a way often found in relevant industries which includes ‘gateways’ or checkpoints and a suggested timeframe. Gateways were non-graded opportunities for feedback and guidance on the laboratory methods and findings during the laboratory sessions. There would be 3 gateways structured as semiformal assessments of progress. Examiners would evaluate the required deliverables up to the point of each gateway in order to allow for the team to proceed to the next stages. The deliverable elements during the gateways were necessary parts for the final assessment. It is argued in Gibbs (1999) that assessment is a main element in student engagement and that it can be used strategically. The gateways were in addition to the regular contact with the students during the laboratory sessions. The three gateways and deliverables, with the suggested timeframe were:

1. Analysis of existing products (recommended 4 weeks)
2. Choice of product and improvements or general idea for new design (recommended 2 weeks after gateway 1)
3. Detailed development of new designs and presentation with demonstrator (recommended 5 weeks after gateway 2). The presentations were held at the end of the project and teams were expected to highlight the main points of their reports and showcase their demonstrator within 20 min scheduled slots. An open trade show styled exhibition event would follow the presentations.

Gateway 3 would be open to other members of staff who would like to attend the presentations. After the presentations, a small trade show formatted exhibition would follow. Several colleagues attended the event and gave feedback to the students. The aim of this would be to also enable students to learn by explaining (Ploetzner et al., 1999). The event was scheduled near the end of term and a bit before the deadline for the report submissions so that students could incorporate the feedback or clarify aspects of their reports.

Technical support and three lecturers were assigned for the regular lab sessions. The tutors would monitor the methodology, team dynamic, and progress of each team. Discussions and recommendations were regular. During gateways, all tutors would be involved in giving feedback, and teams would either fail or pass to the next stage. If the teams failed a gateway, then specific guidelines and a timeframe would be given for the corrections.

A small budget was secured through the engineering department teaching funds that was aimed to cover parts for the practical development of the demonstrator. Teams had a deadline to submit their “shopping” list and apply for approval within a limited allowance. Technical staff was also involved in evaluating and consulting the students with regards to existing resources, alternatives, procuring and assembling the relevant parts.

Assessment was subject to a two-stage moderation process, i.e. one before and one after the assessment. Firstly, any details related to the assessment (e.g. clarity of information and the assessment criteria) were considered by a member of staff outside of the module team. Secondly, the awarded grades were considered by both the module team and an additional member of staff, to check for consistency and fairness across the cohort for the submitted work.

Within the report a section was dedicated to methods in which the students would have to describe the methods that were followed during the different stages of the project as well as roughly outline the parts in which each member of the team was involved.

Additionally, peer review forms would be circulated after the report submission deadline. The peer review forms were optional and confidential. The forms were structured in two sections. The students would either fill the first section in which according to their opinion all members of the team contributed about equally to the project, or the second section in which they would rate each member of their team (including their self) between 0-5, were 0 would be virtually no contribution or absence, 3 about average contribution in relation to all members, and 5 contributing significantly more than other members of the team. Additionally in this section, the students would have to state the parts of the project in which each member contributed.

No action in terms of grade differentiation would be considered in cases of minor differences of perceived contribution. The forms would be actionable only in the case of multiple members agreeing in someone's extremely low contribution. Peer assessment information would also be checked with engagement and attendance. The aim was for the grades to be capped by the grade of the collective effort and then if necessary, to equitably differentiate based on significant discrepancies in contribution.

DISCUSSION

The students were assigned into 7 teams and aspects of team working were addressed. The importance of establishing an environment where people can comfortably contribute ideas was emphasized. Arguably, there is a synergistic potential in well-functioning teams. The aim was to encourage engagement and the development of a sense of ownership for the project, from the whole team, by removing potential barriers to engagement and contribution. All teams worked reasonably well and produced great results (Figure 1). On occasion tensions might arise between team members and particularly around deadlines. This is not uncommon in professional life. It is important for students to learn how to manage such situations (Patterson, 2002) and resolve them as educated adults. Engineers often have to work in teams with colleagues that are assigned rather than chosen. A variety of personalities, working styles specialties may be clustered with the purpose of achieving a specific goal. The module offered a controlled environment with limited professional risk and controlled pressure so that the students could develop some of the necessary skills for collaborating with multiple people under the pressure of deadlines and limited resources. Confidential peer assessment forms were circulated. No actionable peer assessment resulted from the process.

The student feedback from anonymized questionnaires regarding the module, was very positive. Through the comments, students had particularly enjoyed the practical aspects of the module and found it to cater to their interests. The connection between the theoretical parts (even of other modules) and the practical side of this module became apparent especially during the analysis of existing products and the improved design.

The multifaceted nature of the projects included a variety of tasks to be distributed amongst the team members. Both theoretical and practical tasks were required for the completion of the projects. This would allow students to utilize different strengths they might have (e.g., as a result of a different educational background) or be encouraged to push themselves outside their comfort zones and try to develop skills they might be lacking (e.g., written English, presentation skills etc.). It was stipulated by tutors that this would be the opportunity to try and get feedback e.g., gateways on different tasks in order to develop new or hone existing skills. Multifaceted teaching is supported against the previously thought learning styles model (Husmann & O'Loughlin, 2019) and perhaps adds to an inclusive framework.

Coursework was moderated according to an internal review system. Although grades is not necessarily the most accurate measure of teaching effectiveness, the students achieved higher grades than the general average and regardless of educational background. None of the engaged students failed the module. Attendance and engagement was at very good levels.

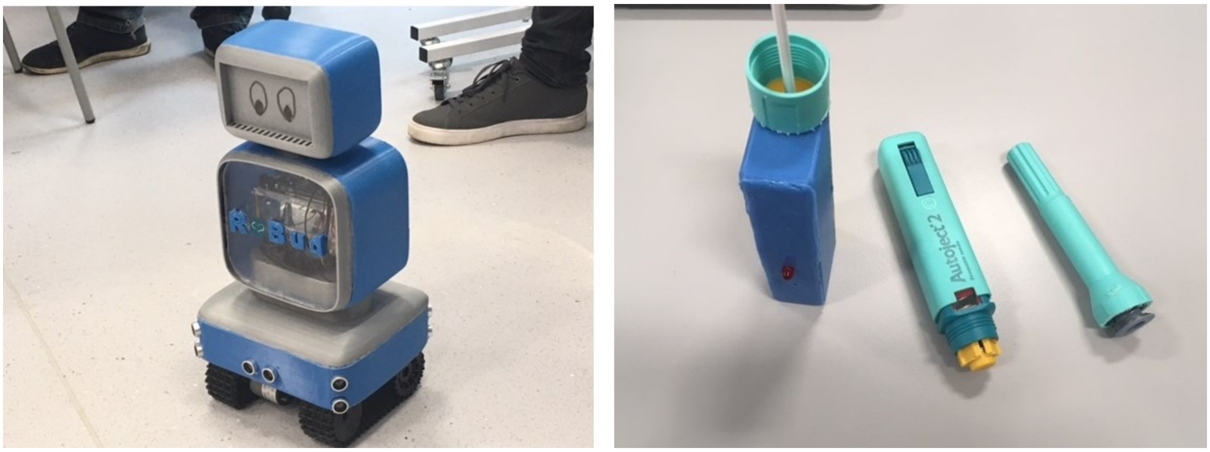

Figure 1. Examples of student demonstrators (left) a remotely controlled robot from a phone application with an additional option for autonomous random movement and with obstacle avoidance, (right) a commercially available injection delivery device that was modified by students to include an audio-visual signal upon drug delivery completion. Both demonstrators performed well and were parts to more general concepts that the students were proposing. Image's courtesy of Edward-Joseph Cefai, Erfan Sakhi, Shanice Ria Tarbert, Sophie Harrison (left) and Agho Omoragbon Ederhumnwu, Jefferies Thomas, Lawrence Clayton, Lee Anthony, Peverill-Jones Jacob, Rodney Munashe Moses (right).

The staff that attended the exhibition event engaged with the students, and prompted them with regards to their work. Colleagues enjoyed the event and shared positive comments. Some of the demonstrator prototypes didn't fully work due to bugs and system glitches which would be expected given the short time scale. However, the students managed to show most of the main features and concepts they had developed.

The projects included tasks that could be performed either during the lab session or independently and then integrated in the project. Several students might need to work in jobs outside the University and in parallel to their studies, and perhaps they would miss some or part of the sessions. The module format was designed to have some tolerance to individual working habits and scheduling needs and therefore being more inclusive.

Students would help each other across teams based on their course e.g. electronics students helping other teams with the electronic aspects of their demonstrator. There wasn't any deliberate competitive element in the design of the module. Peer interactions were encouraged i.e. discussion and communication between teams, as Brame & Director (2016) also suggests that active learning that includes peer interactions may promote the development of 'extended and accurate mental models'. Whilst fellow students from other teams were allowed to assist in elements of the development e.g., debugging, tutors monitored the process to ensure that there was no outsourcing. The development of the demonstrator was only a part of the assessed work however it seemed that it was perhaps the most exciting.

This was generally a very engaging and exciting module both for students but also for staff. Excitement can be a positive element in module development (Bonwell & Eison, 1991). However, this was very resource intensive in terms of staff time and ordered parts cost. Modules including prototyping and development tend to be more costly than theoretical modules. This might become an issue in terms of the scalability of the module. Part of the module success was the staff to student ratio and the ability to dedicate personalised attention. The staff was familiar with the state and progress of the teams. This would allow for staff to anticipate and catch any problems early in order to advise students in applying corrective actions. Significantly, higher student numbers might dilute the amount of individual attention and the resulting student experience might vary.

CONCLUSION

The design of a practical element within an engineering curriculum was described above. The aim was to design a module with student achievement in mind and using elements that would enhance an inclusive frame. Arguably, inclusive and practical methods can be professionally relevant and educationally beneficial. Ultimately, achievement and inclusivity is not just about achieving good grades but achieving in career goals and realizing individual potential. A well-structured and implemented curriculum would provide students with the tools for both. I believe the designed module took deliberate and informed guidance from both literature and industry in order to form an inclusive environment for students to develop and perform.

Challenges in equitable marking, ensuring smooth collaboration between students and effectively scaling the module to higher student numbers, potentially by also using more online tools and resources, would be consideration topics for the future. Feedback and ideas from students and colleagues will continue to inform future planning and module design.

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BIOGRAPHICAL INFORMATION

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C PROGRAMMING LANGUAGE TEACHING BASED ON CDIO

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ABSTRACT

"C Language Programming" course is a professional basic course for most engineering majors, which is set up in the first year of undergraduate programmes. It is an important basic course to cultivate students' computer programming ability. The traditional C Language teaching adopts the training method of programming on PC only, the course content is basically around scientific calculation and algorithm design, which is insufficient for students' programming training based on practical engineering problems. This paper introduces the application of CDIO teaching mode in the teaching of "C Language Programming" in Automation Major of Beijing Institute of Petrochemical Technology(BIPT). The isolated programming course and practice are put into the specific automation system, and the "engineering object teaching method" is adopted to integrate the four links of CDIO " Conceive, Design, Implement and Operate" and the key knowledge points of programming into a series of practice projects, the learning mode of "task practice → skill induction → knowledge summary → project re practice" is adopted to train the programming ability. From the teaching practice effect of the course, this mode can promote students' knowledge acquisition activities to be more active, more practical and more effective, improve students' learning quality, and comprehensively improve students' knowledge, ability and professionalism. While learning C Language, the students have "early engineering experience", which can improve their interest and confidence in future professional courses.

KEYWORDS

C Language Programming Teaching, Engineering Object Teaching Method, Early Engineering Experience, Learning by Doing, Standards: 2, 3, 5, 6, 7, 8, 9, 10, 11

INTRODUCTION

In China, there is a lack of effective transition and connection between the basic education in middle school and the engineering education in University. In middle school, there is a lack of engineering practice ability training, and students enter the university to study engineering with almost no professional perspective. For the C Language course set up in the first year of University, students do not know the application needs of the programming knowledge in the professional problems in the future. The traditional C Language teaching method is based on PC programming to learn C Language grammar. Most of the practical problems are confirmatory, students cannot get real ability, and even breed boredom. This will lead to students in the third grade learning professional courses need to program when unable to start. Knowledge is mastered but not applied.

Contemporary college students are in the information age. They use all kinds of application software with powerful functions and gorgeous interfaces every day. They have high learning expectations for programming courses and are interested in how to compile computer programs. However, they are not interested in traditional teaching contents such as inputting 10 numbers to get the average value. The traditional teaching method of programming course is still based on learning grammar. The confirmatory cases used to study grammar are simple and boring, and the comprehensive algorithm cases used to cultivate comprehensive ability suddenly increase the complexity. It has higher requirements for students' mathematical foundation or abstract thinking ability. It's hard for students to imagine how the program works in the computer. There is a big gap between the content of programming course and the function of computer software commonly used by students. This leads to students' lack of interest and initiative in learning. Lack of interest in learning, the effect is very poor, naturally cannot reach the engineering consciousness and innovative thinking of high-level training objectives.

Therefore, we need to start from the professional training objectives, reverse design C Language curriculum objectives, modify the curriculum content, break through the traditional teaching methods, to solve the problems of abstract, boring, difficult to learn, poor learning effect and poor application ability of "C Language Programming" course.

Returning engineering education to engineering is an important strategy of modern higher engineering education reform, and CDIO is an effective educational means to realize this strategy. CDIO standard 2,3,5,6,7,8,9,10,11 provides a framework for the reform of C Language teaching in grade one. Integrating knowledge learning and engineering vocational training, C Language teaching is carried out around the typical robot production project. From the continuous engineering application practice, the common programming knowledge and key skills are summarized, and the ideas of analyzing and solving problems are established. Then these knowledge and skills are re applied to the new programming practice, to achieve the ultimate goal of C Language learning.

FRAMEWORK OF C LANGUAGE TEACHING BASED ON CDIO

The Orientation of "C Language Programming" in Professional Training Program

Since 2015, BIPT has implemented "C Language Programming" teaching based on CDIO in Automation Major. Automation Major passed the Professional certification of Engineering Education in January 2017. Under the background of professional certification, according to the positioning of "C Language Programming" course in the course system of Automation Major, the reverse course design is carried out with the guidance of students' ability cultivation, and the course objectives are determined.

The training goal of Automation Major is "automation system engineer oriented to production line". To train students to solve complex engineering problems of automation system engineering design, product integration, operation and maintenance, and technical service, the following five professional engineering abilities are mainly cultivated: the Application Ability of Mathematics and Natural Science, Humanities and Social Science Knowledge; the Comprehensive Design Ability of Electronic System and Computer Programming Ability; the Analysis and Design and Digital Simulation Ability of Automatic Control System; and the Automatic Control Department Integrated Design, Product Integration, Installation, Commissioning, Operation and Maintenance Capabilities; Enterprise Practice Capabilities. In order to cultivate these five engineering abilities, the corresponding curriculum modules need to be designed for the professional education training program, as shown in Figure 1.

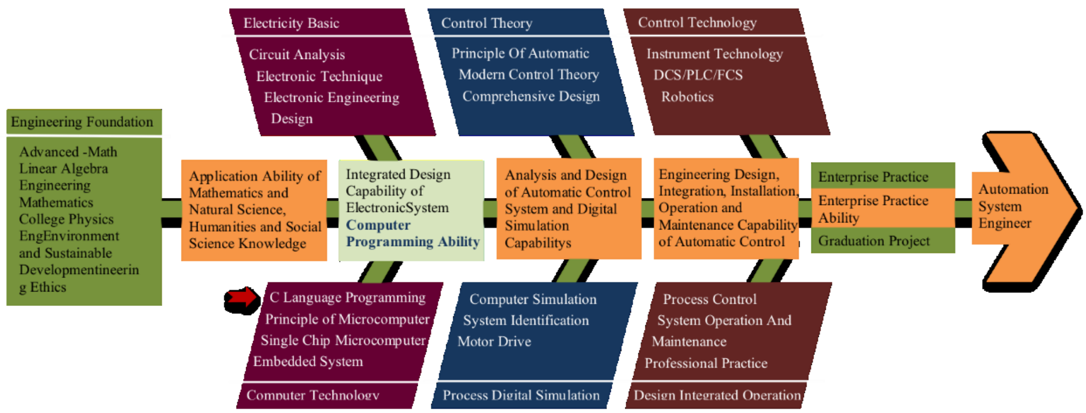

Figure 1. Fishbone Diagram of Training Program Course Module for Automation Major

The course of "C Language Programming" is an important basic course of computer technology module in the training plan of Automation Major for freshmen. It provides strong support for the cultivation of computer programming ability in the five modules of professional ability cultivation. The relationship matrix between the course objectives and 12 Graduation Requirements is shown in Table 1.

Table 1. Supporting Matrix of Course Objectives for Graduation Requirements

Category	Graduation Requirements	Teaching Objectives
Knowledge	Engineering knowledge	**Objective 1:** Master the basic grammar system of C Language, the ideas and methods of structured programming, have the ability of abstract and automatic computing thinking, and be able to use it in programming.
Ability	Design/ development of solutions	**Objective 2:** Have basic programming and algorithm analysis ability, be able to skillfully use C Language to compile basic programs of sequence structure, selection structure and circulation structure, be familiar with common algorithms such as search and sorting, be able to design and implement program modules according to requirements, reflect innovation consciousness, and consider cultural and environmental factors.
	Modern tool usage	**Objective 3:** Familiar with the software development process, with the basic quality of software development, can skillfully use Microsoft Visual C++ 6.0 or at least one other development environment for programming, debugging and testing; have more standardized programming habits and good programming style; establish the spirit of communication and team cooperation in the process of software development, and consider the awareness of engineering practice in the selection of project scheme in addition to technical perspective.
Professionalism	Individual and teamwork	**Objective 4:** Has the ability of team cooperation, understands the individual role division in the team, and is competent for the corresponding role responsibility achievement.
	Communication	**Objective 5:** Be able to communicate effectively on complex engineering problems in the computer field, including writing reports and design manuscripts, making statements, clearly expressing or responding to instructions.

Framework of C Language Teaching Based on CDIO

Based on CDIO standard 2,3,5,6,7,8,9,10,11, the implementation framework of C Language teaching is constructed, as shown in Figure 2. The C Language teaching framework based on CDIO includes the following aspects:

- Construct the engineering experiential practice training environment of C Language learning.
- Redesign the curriculum objectives, teaching methods and teaching evaluation.
- Teacher training to improve teachers' engineering ability.
- Teaching implementation, effect evaluation and feedback.

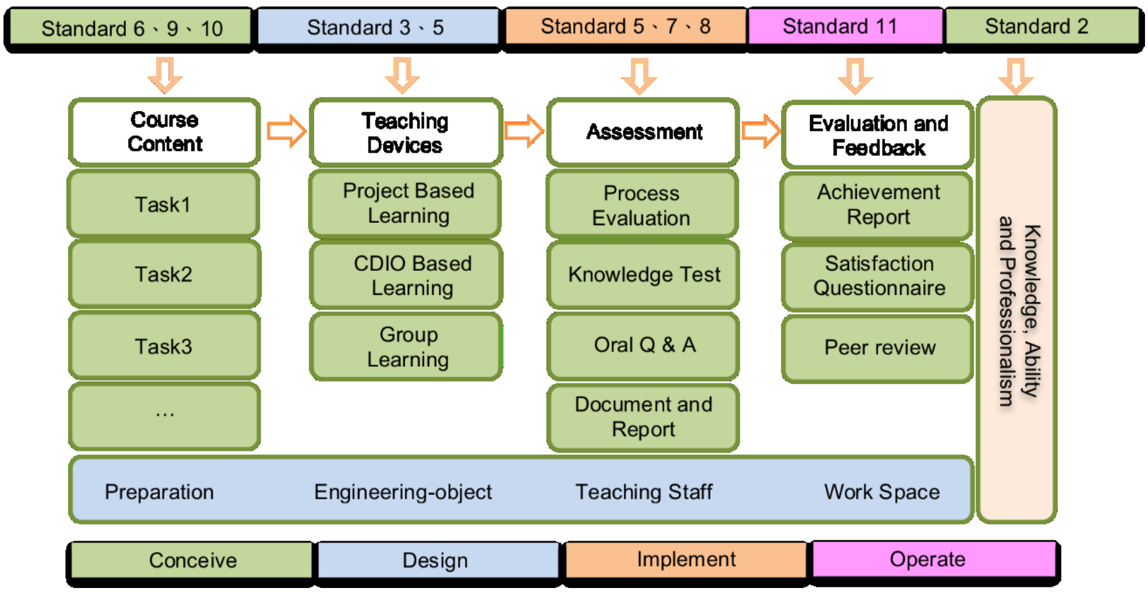

Figure 2. Framework of C Language Teaching Based on CDIO

IMPLEMENTATION OF C LANGUAGE TEACHING BASED ON CDIO

Selection of Engineering Object

In recent years, the rapid development of Educational Robot provides a very suitable engineering object for the engineering education reform of "programming" course. Educational Robot is a kind of robot products, suits or parts specially developed by manufacturers to stimulate students' interest in learning and cultivate students' comprehensive ability. Educational Robot not only provides a variety of programming platforms, but also allows students to disassemble and assemble freely, and allows students to design some parts by themselves.

The following principles should be followed in the selection of Educational Robot in the construction of engineering experience environment of C Language course:

- After simple training, students can understand the hardware structure which have simple perception and mobile functions, and provide I/O expansion interface;
- Support C Language programming and provide suitable software development environment;
- Manufacturers provide appropriate supporting materials and teacher training services.

For example, the C51 series MCU chip as the controller, the main body of wheeled robot, C Language programming development environment, and a variety of supporting sensors are very suitable for C Language teaching and early engineering experience. Figure 3 is a few pictures of the engineering object for C Language teaching, which is a wheeled robot car, called "Dragon Baby Car".

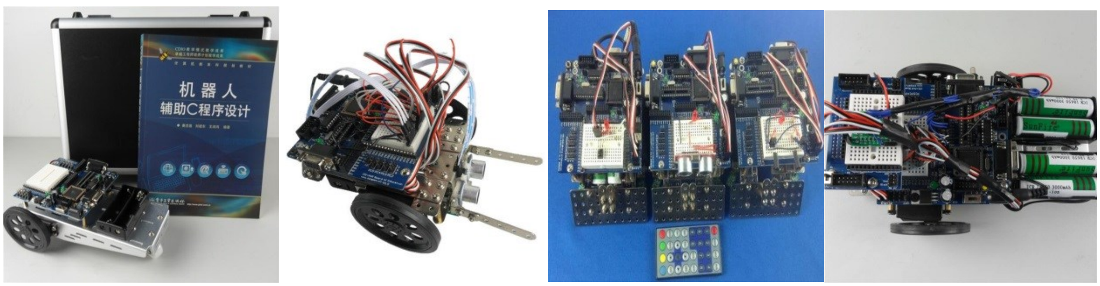

Figure 3. C Language Teaching Robot (Dragon Baby Car)

Course Content

The content of the course is changed from data processing and algorithm research to C Language teaching about a series of production projects of Educational Robot, as shown in Table 2. According to the learning mode of "task practice → skill induction → knowledge summary → project re practice", it breaks through the traditional learning mode of "classroom teaching + programming training on PC", integrates knowledge, ability and quality, and cultivates students' comprehensive ability and advanced thinking to solve complex problems. At the same time, the most basic engineering quality of students is cultivated.

Table 2. Contents of Robot-aided C Language Programming Course

	Task Description	C Language Syntax	Solving Engineering Problems	Professionalism
Task1	Let the robot run the first program	Understand programming, compiling, downloading and running, master the basic framework of C	Can use the integrated development environment to create projects, compile c Language source program, and download to the MCU	Understand the operation of program on MCU
Task2	Robots do arithmetic	Master the basic data type and data operation of C Language	Be able to program sequence structure for data calculation	Understanding computer memory
Task3	Robot walking square	Master the syntax format and operation mechanism of C language cyclic structure	Can program the cycle structure to control the robot to get continuous pulse signals	Understanding the relationship between program output signal and robot motion
Task4	Tactile navigation robot	Master C language choice structure syntax and operation mechanism	Can control the robot to avoid obstacles and cruise automatically by using structure selection program	Understand the control system structure composed of "sensor controller actuator"
Task5	Programming function to realize robot cruise control	Master the definition, call and declaration of user-defined function	Can program functions to realize the basic cruise action of robot	Understand the modular programming idea of top-down divide and rule
Task6	Cruise control of robot with complex path	Master the definition of array and the reference of array elements	Can store path information in array and realize cruise control of complex path robot by programming	Establishing the program design idea of "data structure + algorithm"

Task7	Design and development of integrated project - Intelligent Handling Robot	Simulate the actual working process of the automatic logistics system, use the sensor to control the robot to patrol the line in the given map, and carry the material blocks in the material area to the target area according to the requirements.
Task8	Design and development of integrated project - Robot Tour in China	In a given site, travel to the attractions in the site map as required. There are 15 scenic spots in the site. The robot starts from the starting point, moves according to the path of the patrol site, travels in the specified scenic spots within the specified time, and returns to the starting point after visiting the scenic spots.

According to CDIO standard 5, the course content is divided into two levels, task 1 to task 6 as the basic level, task 7 and task 8 as the advanced level, so as to achieve the high-level learning objectives.

Early Engineering Experience

The reform of China's engineering education is facing a social problem. The disjunction between examination-oriented education in primary and secondary schools and professional education in universities makes many engineering students lack the most basic understanding of engineering before they enter the University, and their engineering experience is zero. In order to solve this problem, some universities began to learn from international advanced engineering education experience. In order to create an early engineering practice environment for students and provide early engineering experience, universities in many countries have set up engineering experience courses for freshmen. "It aims to provide students with the first year's engineering experience to cultivate professional skills, establish a professional perspective, and understand the social and humanistic environment of the engineering world" (Fei Y. N., 2008).

In the book "Rethinking Engineering Education: CDIO method", Professor Edward Crawley and his co-author of the Department of Aeronautics and Astronautics Engineering of Massachusetts Institute of technology in the United States compare the architecture of engineering knowledge with the structure of a stone arch (Figure 4), and illustrate the role of each level of knowledge with the arch construction process (Crawley E. F., 2007). Among them, the guiding course "early experience course" is like a wooden frame built at the beginning of arch construction, which determines the shape of the arch and the relationship between various stones. Without the construction of this primary frame, no matter how good the stones can form the arch, we can see the important basic position of "early engineering experience" course in engineering education.

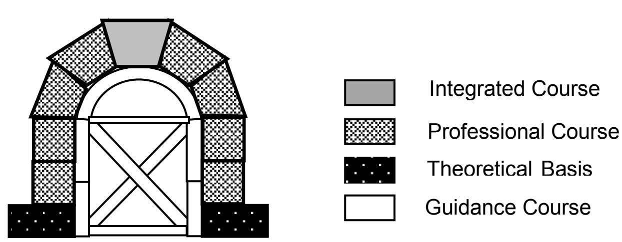

Figure 4. The Structure of Engineering Knowledge System with Arch Analogy

However, there are many practical bottlenecks in the teaching implementation of adding engineering foundation course in the whole university, which leads to the fact that it has not been popularized in China. Therefore, it is a good way to solve the problem to integrate the content of early engineering experience in the C Language course for freshmen. It's a win-win solution.

"Project Oriented" Teaching Organization Mode

Due to the difficulty and challenge of the course content, the teacher decomposes the comprehensive task into several task modules according to the students' cognitive rules, designs the progressive practice content and process, and integrates the basic data representation, logical control structure, function encapsulation and call, combined data of C Language into a series of project task production. Adopt the project teaching organization mode, with 3 ~ 6 students as a team to complete related tasks, each team has a project leader, who is responsible for the organization and coordination of team tasks, and each student in the team undertakes independent program module development. It realizes "learning by doing" and "doing by learning" and realizes the interactive and inquiry learning of teachers and students (Figure 5). To cultivate students' practical ability, innovative ability and engineering quality.

Figure 5. Learning by Doing

Course Assessment

Adopt scientific and diversified assessment methods. The teaching objectives, teaching process, assessment methods and the degree of achievement assessment are related, the process assessment is strengthened. For the process assessment, the evaluation scale (Table 3) is designed to realize the supervision and evaluation of the whole learning process and make a scientific evaluation of the teaching effect.

Table 3. Process Assessment Scale

No.	Item	Ratio	Evaluation Criterion
1	Attitude	0.3	Conscientious attitude, rigorous style; according to the schedule to complete the design task; can well complete the required workload.
2	Ability	0.3	The ability of computational thinking, the ability to solve problems, the knowledge of software and hardware of computer application system, the ability to analyze and solve problems with the thinking mode of C language, and the ability to put forward effective program design scheme; Design simple data structure and algorithm; use programming language to realize algorithm description; program to solve problems.
3	Team	0.2	Have a clear division of labor and distribution ratio, clear their responsibilities; can play their role in the team; team work is effective; in the process of project implementation, can discuss with each other; reflect the work content and its requirements for personal knowledge, ability and quality.
4	Written Expression	0.1	Complete the design report, try professional written expression, use drawing flow chart to express personal design intention; use algorithm to solve problems; be able to realize system design, program design and input and output operation comprehensively.
5	Oral Q & A	0.1	Answer all kinds of questions accurately and fluently, be able to clarify their own point of view, answer the questions concisely and to the point, highlight the key points; understand the questions, according to the known conditions, find out the mathematical method to solve the problem or establish the corresponding mathematical model.

According to the homework, process evaluation and final examination results, the achievement degree of teaching objectives is determined by using the course assessment score analysis method. The final results are filled in Table 4.

Table 4. Calculation Table of Achievement Degree of Teaching Objectives

Course Name		**C Language Programming**						
Teaching Objectives		1	2	3	4	5		
Ratio		0.3	0.3	0.2	0.1	0.1	1.0	
Teaching Link								
Classroom Teaching		√	√	√	√		/	/
Experimental Operation		√	√	√	√	√	/	/
Comprehensive Design		√	√	√	√	√	/	/
Assessment method	Ratio	The Ratio of Assessment Links to Teaching Objectives					∑	Score
Homework	0.2	0.2	0.8	/			1	
Process Evaluation	0.4	0.2	0.2	0.2	0.2	0.2	1	
Final Exam	0.4	0.2	0.7	0.1			1	
∑	1.0	0.6	1.7	0.3	0.2	0.2	3	
Achievement of Teaching Objectives								

Achievement of Teaching Objectives

Figure 6 shows the achievement of teaching objectives of C Language Programming course for Automation Major in recent three years. About 90 students participate in the course every year. It can be seen from the chart that the teaching effect of the course is improving year by year.

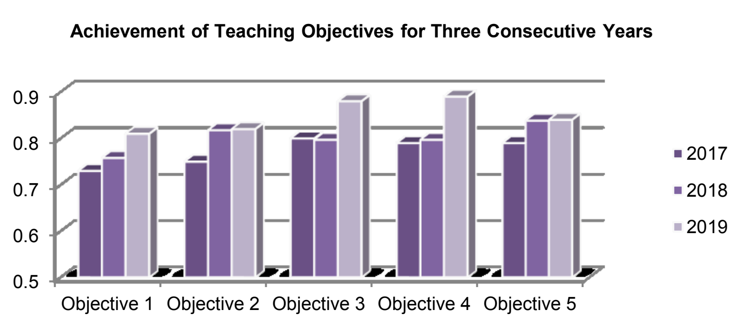

Figure 6. Achievement of Teaching Objectives in recent years

Questionnaire on Students' Learning Outcomes

In order to evaluate students' satisfaction with the course harvest, a questionnaire was designed, including 12 questions, as shown in Table 5.

Table 5. Students' Learning Satisfaction Questionnaire

No.	Questions	Evaluation (3-Agree, 2-Uncertain, 1-Disagree)
1	Be able to deeply understand the importance of programming in this major	
2	Strong interest in programming	
3	Understand the basic concepts of variables, data types, expressions, arrays, functions, pointers, etc	
4	Be able to skillfully use selection structure and cycle structure to write programs to solve problems	
5	Have the ability to analyze problems, be able to program multiple functions	
6	Have the ability to run, test and debug the program	
7	It has good code style and pays attention to the interface design between program and user	
8	Master the basic idea of program design, understand the working principle of computer	
9	Willing to actively participate in class discussion and group learning	
10	Can improve oral and written communication skills	
11	It improves the engineering ability and cultivates the entrepreneurial spirit and innovation skills	
12	Cultivate the quality of persevering to achieve the goal	

According to the students' learning satisfaction questionnaire in Table 5, 88 students from 2019 were investigated, and 82 questionnaires were collected. The statistical results are shown in Figure 7.

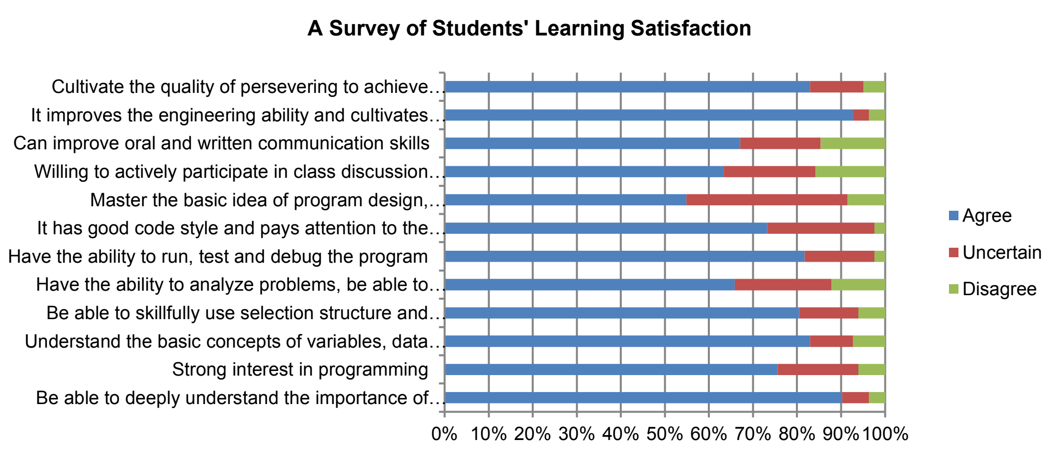

Figure 7. Students' learning satisfaction, taken in July 2019

In 82 questionnaires, more than 90% of the students can deeply understand the importance of programming in their major, and think that they have improved their engineering ability, cultivated their entrepreneurial spirit and innovative skills. More than 80% of the students agree with the achievement of ability training. On the whole, students are basically satisfied with their learning process and achievements, which confirms the effectiveness of CDIO principle in the course.

CONCLUSIONS

According to CDIO standard, combining programming with practical engineering objects, C Language teaching is carried out in the form of "learning by doing", which stimulates students' interest and enthusiasm in programming, improves learning efficiency and effect, and is well received by students. Students sigh that "robot based programming practice connects the knowledge of C Language with the robots we are interested in, which makes us immerse ourselves and enjoy it all the time". Students summed up that "group training is the first, the training process should be patient, ask for more advice when encountering difficulties, and think more when facing problems".

The effect of the course brings about the improvement of students' programming ability and engineering practice ability. It greatly promotes students' self-confidence, enthusiasm and participation in innovative practice activities. Fruitful results have been achieved.

The first year's C Language course provides students with early engineering experience, helps students establish a professional perspective, and lays a solid foundation for subsequent professional learning. With the smallest incremental investment in teachers, equipment and management, the maximum benefit has been obtained.

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NAVIGATING UNCHARTED WATERS: A ONE-YEAR GERMAN-FINNISH FACULTY EXCHANGE

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ABSTRACT

This paper describes the decision of two higher education teachers from Finland and Germany not to leave internationalization solely to their students and the exchange that ensued, which took place over the full academic year 2020/2021 with the enthusiastic support of the participants' institutions, universities of applied sciences located in Turku, in the south of Finland, and Hamburg, northern Germany. The paper will reflect on our personal experience of the exchange and our perceptions of teaching-related differences between the participating institutions, alongside conceptions of pedagogy and their influence on the competencies we expect of and test in our students. Though we intended to keep the exchange as simple as possible, we soon learned that the conditions associated with health insurance and employment contracts posed significant challenges to our project. It was impossible to simply extend a one-week exchange, of the type frequently undertaken and familiar to the higher education scene, to a full year. The project raised numerous administrative issues in both institutions, neither of which had blueprints setting out how to tackle them. All these challenges notwithstanding, this paper tells a success story. While some of our approaches in relation to the exchange will not translate entirely to other settings, the key message remains: the exchange added value both to the personal lives of the families that spent the academic year in another country and to the organizational development of the institutions involved. The exchange additionally represents a good example of faculty development in line with CDIO (Conceive, Design, Implement, Operate) principles and of implementation of the new optional CDIO standard regarding internationalization and mobility.

KEYWORDS

Internationalization, higher education, exchange, PBL, Standards: 4, 5, 6, 8, 9, 10

INTRODUCTION

Internationalization creates value particularly for export-oriented countries such as Finland and Germany. Both policymakers and those responsible for strategic organizational development in higher education (HE) institutions recognize this fact and attempt in this context to address the challenges of preparing students for careers in multinational teams within organizations that operate across country borders. Interaction and communication among people from a range of cultural backgrounds, at individual and institutional level, are integral and indispensable aspects of any academic education. For the two HE institutions that are the subject of this paper, Hamburg University of Applied Sciences (HAW Hamburg) in Germany and Turku University of Applied Sciences (Turku UAS) in Finland, cultural diversity therefore represents significant capital for the advancement of their research, teaching and degree programs.

In this context, internationalization is a key pillar of HAW Hamburg's development and emerging institutional profile. International connections and academic collaboration with partner institutions across the globe are boosting the institution's competitiveness and attractiveness to potential students and staff, as well as being vital to the formation of early career researchers. The internationalization strategies of both HAW Hamburg and Turku UAS have defined 'internationalization at home' as a key area for action. This concept encompasses, alongside other measures, the internationalization of degree programs and teaching to the end of improving institutions' full inclusion and incorporation of researchers from abroad into teaching, giving their curricula a stronger international emphasis and flavor, and enabling them to offer a greater number of English-language modules and classes (Hans de Wit, 2015). Accordingly, HAW Hamburg has established a specific international mobility fund for teaching staff and provides financial support for the creation and implementation of curriculum development measures that center on internationalization. Increasing the proportion of teaching faculty with international experience is of central importance to the progress of internationalization. Such individuals contribute crucial new content, insights and points of view to teaching, help internationalize degree programs, and strengthen links with institutions abroad. International mobility enables faculty members to exchange ideas and gain new insights and has thus a strong impact on faculty development.

All this said, the incentives for educators and administrators at HE institutions to initiate and organize international exchanges of faculty members are currently limited, and the two-year preparatory phase that led up to our exchange was replete with hurdles to clear, calling on all our reserves of enthusiasm. Having successfully carried out the exchange, we – the authors of this paper, each of whom was directly involved in the process in one way or another - are firmly convinced that the endeavor has reaped plentiful rewards. We would caution, however, that anyone planning an international exchange at faculty level should be aware of the extent of individual and organizational effort and goodwill required from all involved.

Finland and Germany: a comparative overview

Finland is one of the northern states in the European Union (EU), usually considered as part of Scandinavia, although Finnish, unlike the other primary languages in this region, is not a North Germanic language. Germany is geographically in the EU's center. The historical ties between the two countries remain evident today. One of the most noticeable differences between Germany and Finland is in population density, Germany having 234.7 inhabitants per

km^2 and Finland 18.1 per km^2 (eurostat, 2020). Nevertheless, the proportion of residents living in urban areas is higher in Finland (85.5%) than it is in Germany (77.5%).

Finland and Germany share comparable demographic issues, with total fertility rates well below 2 in both countries, leaving them – and the two institutions that are the subject of this paper - facing similar challenges with regard to attracting sufficient numbers of students. Differences in the field of education include a marked divergence in public spending on education as a percentage of GDP; in 2016, Finland was eighteenth in the world (6.9 % of GDP), while Germany was at position 73 (4.8 % of GDP). Admission to higher education also follows a different route in the two countries. After nine years of joint basic education, Finnish pupils can either obtain a vocational qualification or continue with general upper secondary education (*Lukio* (fi) / *Gymnasium* (sw)) leading to a matriculation examination. Both tracks take another three years. About 40 % continue with vocational training and 54 % with upper secondary education, with those not remaining in education amounting to a small minority of 2.6 % (Statistics Finland, 2020). Both tracks lead to eligibility to apply for higher education, which works on a twofold system offering research-centered universities and more practically- and vocationally-oriented universities of applied sciences. ~~Reference (Finnish Education System, n.d.) provides ~~A~~a~~n overview of the Finnish education system's structure can be found at the Finnish Ministry of Education's web (Finnish Education System, n.d.). In Germany, admission to higher education is the preserve of those who have completed academic secondary schooling (*Gymnasium*) or those holding a particular level of vocational education culminating in acquisition of the status of technician, *Meister* (master tradesperson) or an equivalent. At tertiary level, proportions of the total population who have attained a degree (cumulative figures for Bachelor's, Master's, and doctoral degrees or equivalents) are very similar, standing at 19.2 % in Finland and 18.5 % in Germany. Universities and universities of applied sciences have similar statuses and missions in the two countries, and educational tracks which cross from a university to a university of applied sciences or vice versa are - in principle - possible in both.

HIGHER EDUCATION

In Finland, the Ministry of Education and Culture is responsible for the planning and implementation of higher education and science policy and preparing statutes, national budget proposals and government decisions that apply to them. The system consists of 13 universities and 22 universities of applied sciences (Higher Education and Science, n.d.). Universities of applied sciences are legal entities and are usually maintained by a public limited company. They have extensive autonomy over their research, teaching, and internal administration. The Ministry's principal steering instrument is funding, determined in annual negotiations with the universities of applied sciences (Ministry of Education and Culture, n.d.). Degree programs set out their specific content, and the teaching and assessment methods used, in their program descriptions and program implementation plans respectively, with considerable scope for faculty members charged with individual and team-based course delivery to choose how they wish to implement and assess a program.

In Germany, education is within the remit of the federal states, among which provisions may vary to some extent. Each state's education authority steers the development of HE institutions by defining overall generic targets which are associated with minor financial grants. HE institutions manage the delivery of their programs via self-administration bodies which control many aspects of teaching delivery in what is, certainly compared to Finland, a striking level of detail. Higher education institutions may be state or state-accredited (universities, universities of applied sciences and colleges of art and music) or private; most of the latter are universities of applied sciences. ~~Overall~~Overall, there are 397 higher education institutions in Germany (Higher Education System, n.d.). ~~(German Rectors' Conference, n.d).~~ Universities are the only institutions that can confer doctoral degrees in their own right; universities of applied sciences feature a strong emphasis on education and research that engages with real-world and practical settings and applications.

The institutions involved in the exchange described in this paper are located in the cities of Hamburg and Turku. Turku is the sixth largest city in Finland and Hamburg the second largest in Germany. However, their populations differ considerably, with 0.18 million people living in Turku and 1.8 million in Hamburg. Both institutions are universities of applied sciences, attract a significant number of students from their surrounding regions, and serve as significant economic factors in their cities. Turku UAS is one of the largest institutions of its kind in Finland (Turku University of Applied Sciences, 2020). Established in 1992, it currently offers Bachelor's and Master's degree programs for about 9,600 students across three faculties: Engineering and Business, Health and Well-being, and Arts Academy. It also offers courses at the Open University of Applied Sciences, in-service training, and research, development and innovation (RDI) services to businesses and other organizations. The Turku Open University is of particular interest to German HE, as it constitutes an innovative complement to more traditional academic tracks: anyone ~~resident in Finland~~ can enroll on its courses and attain credit points that can count toward a subsequent degree course. HAW Hamburg is one of Germany's largest institutions of its type and can trace its history back to 1970. It delivers 40 Bachelor's and 34 Master's degree programs to an approximate total of 17,000 students (as of winter semester 2019/20) in its four faculties, Business and Social Sciences; Design, Media and Information; Engineering and Computer Science; and Life Sciences. HAW Hamburg is engaged in raising and developing its research profile while maintaining its central focus on the excellence of its teaching and degree programs. Of its approximately 17,000-strong student body, 2,649 (15.5 % as of winter semester 2019/20) are international students, originating from more than 100 nations.

TEACHING AND LEARNING IN TURKU AND HAMBURG

As outlined above, teaching with a practical, real-world focus and internationalization are cornerstones of the way universities of applied sciences work. One might expect in this context that HE institutions would embrace the idea of enriching curricula with courses delivered in English; this was, however, to prove a not entirely uncomplicated issue in our cooperation arrangements. Many students also shared a perspective that regarded English, as a language of instruction, as adding to their overall workload. The associated terminology, particularly with regard to technical terms, was new to the students and its management required considerable efforts by students and staff alike.

Andreas Baumgart: a teaching experience from Turku

The classes I delivered in Turku were mostly for undergraduate students and ranged across the engineering curriculum. I was lucky to have colleagues who were willing to offer additional support to students in Finnish during critical phases. I admit, however, to having been rather surprised that in a country like Finland, where most people one encounters day to day are fluent in conversational English, the use of the English language should prove a significant constraint in lectures.

Language, of course, is far from being the only aspect of the complex cultural differences in our social behaviors, beliefs and habits. In Hamburg, I like my students to engage actively in taking on and managing challenging tasks. This means I need to understand where they are in their individual learning processes. I rely on their feedback so I can provide appropriate interventions in class. This approach, challenging enough in Germany, proved beset with issues in Finland. Most of my attempts to initiate interaction with students did not meet with much success, whether they took place in the context of face-to-face events or online plenary or breakout sessions. I used timers set to 60 seconds to ensure I allowed sufficient time for questions or feedback during lectures. This "slow-down" proved to be the aspect of my teaching in Finland to which I found it most difficult to adjust. There were many occasions during live lectures when I wondered whether a recording would not be a more suitable offering for these students. Conversations with exchange students, mostly from Germany, confirmed my impression.

As a specific example of teaching I was involved in during my time in Finland, I will now outline a first-semester project, in the context of a physics-based modeling course primarily delivered by Pekka Jukantupa, Piia Pesso, and Antti Meriö, in which students designed and 3D-printed pumps and "raced" their designs in a competitive game whose aim was to deliver the best-performing product. This class represents a good example of a Design-Implement project as described in CDIO Standards 4 and 5. Students were given some piping, a DC motor and battery and an experimental setup and asked to come up with the most effective water pump. I found that this project's real-world-related creation of an engaging learning experience at a very early stage in students' programs encompassed a number of factors which we in Germany might take as inspiration. The use of student teams in COVID-19 times, with distance learning dominating the student experience, provided students with clearly defined points of contact with others on their program. Further, the collaborative approach employed, with each student required to contribute their part in a time-critical framework during the initial weeks of their studies, appears to me to be a useful way of helping students establish a healthy and productive routine. It is doubtless challenging for some students, new to higher education, to get out of bed each morning, to settle down to work independently, to revise on their own initiative and to produce deliverables on time. This project is likely to have helped them with this. Another result-enhancing aspect of the project is the fact that students are likely to be relatively blunt in letting their teammates know about discrepancies between expectations and performance.

From an academic point of view, the project enabled students to acquire concepts and terminology in basic physics. As centrifugal pumps are among the more challenging subjects in conventional engineering, students had to rely on their intuition rather than on formulae and needed to discuss matters with their teammates without background knowledge in the subject. The project appeared to afford them an opportunity to discover, in a hands-on fashion, the nature of physical phenomena, on which they will be able to draw as they progress to higher semesters. The team working process was supervised and the students were required to document their approach and reflect on their own role in the team.

Being more of a theory-oriented engineer, I found the use of 3D printing as a cheap and hands-on way of producing a "thing" - something tangible - very convincing. If you are unable to attach a pipe to your pump or if more water leaks from the pump than it delivers, then the design is not persuasive. I also noted the competitive nature of the project as generating a positive effect. Competition is known to be a strong driver of motivation, particularly for students whose focus is on high performance. The project's set-up in the form of a competition to create the design with the highest delivery rate supplied an incentive to students to optimize their work. Overall, I experienced the project as evidence of the potential of project-based learning to make study more engaging and enlivening in higher education settings.

Patric Granholm: Teaching in Hamburg

As Andreas Baumgart's counterpart in the exchange, I had the opportunity to teach a class in Applied Computer Science in English, taking on one of three groups comprising the approximately 180 students registered for the course. The other two groups had tuition in German and were considerably larger than the English-language group, in which 40 students had enrolled. The students in the group with tuition in English were offered a complementary language course. A specific problem with the course's implementation was that several students signed up for the course but never showed up, neither did some of them re-emerge once the inevitable initial switching between the groups was complete. None of those who did show up took the supplementary English language course offered by the International Office. A further difficulty was presented by COVID-19, which forced us to hold the course completely online. The online teaching experience did not differ much from my earlier online courses for Finnish students; the issues of activating students and the lack of direct feedback were the same, and the assigned slots for classes and the available teaching materials had been designed with face-to-face teaching in mind. Adjustments and modifications to the course's layout and materials to the end of better supporting this mode of delivery were impossible due to time constraints. All these difficulties notwithstanding, the small, active and respectful group of students that attended made the course a positive experience overall.

INTERNATIONALIZATION

The EU strongly encourages international exchange of both students and faculty via its ERASMUS programs; however, there was no appropriate support structure in place for a one-year exchange of faculty, leaving us required to rely on creating our own and endowing the whole endeavor with a sense of "navigating uncharted waters." The section that follows outlines some of the key points of internationalization at the two institutions involved.

At Turku UAS and HAW Hamburg alike, most classes take place in the language of the country, which students need to have a working knowledge of if they are to benefit from the full range of courses offered at these institutions. Nevertheless, both institutions offer classes specifically tailored to incoming international students, which are usually in English, and language courses for non-native speakers of the local language. In Turku, the International Student Services office assigns peer "tutors" (Turku UAS degree students) to all incoming exchange students and offers the "Get Finternational" course, which aims to bring Finnish and international students together and improve their cultural awareness, to support the peer activities. As a foreign lecturer, I was invited to put on a workshop for outgoing and incoming international students at Turku UAS.

An average of 780 students at Turku UAS are of non-Finnish origin; they include exchange students and those completing their entire degree at the institution. There are no tuition fees for students from the EU and EEA, but fees of 4,000 to 20,000 euros for students from elsewhere (Studis Online, 2020). According to the DAAD, international students in Finland must acquire a command of the Finnish language sufficient to follow a class before they commence their studies. This said, there is an increasing range of English-language programs on offer, for which, depending on the program, a good command of English is required (DAAD, n.d.).

HAW Hamburg offers a wide range of semester courses in English for international exchange students from its partner universities and in the context of the Global E3 (Global Engineering Education Exchange) program, where students would like to study for a semester or a year in Germany but have no or limited knowledge of German. In general, students must choose classes within one program and only those delivered by a department with which their institution has a cooperation agreement. HAW Hamburg runs a buddy and support program titled “weBuddy” for its new international visiting and degree students, which involves experienced HAW Hamburg students helping the newcomers to settle in and find their feet as they commence their studies. When they arrive on campus, they take part in a Welcome Week (or Weeks) including a diverse range of events whose purpose is to help them get to know other students, the campus and the city. A range of intercultural programs of events takes place during semesters. HAW Hamburg runs a comprehensive language program with free-of-charge German courses for international students alongside beginners’ and advanced learners’ courses in seven additional languages, which the institution’s International Office part-funds.

ADMINISTRATIVE REQUIREMENTS AND FUNDING OPTIONS

HAW Hamburg’s International Office supports teaching stays abroad for its faculty with a special mobility fund and Erasmus funds for teaching and job-shadowing stays abroad. Turku UAS also offers Erasmus funds for HE teachers. Both institutions used these funds to support two fact-finding missions undertaken by the faculty members involved in the exchange; they visited their prospective host institution, department and city in advance to explore the proposed exchange’s feasibility. The one-year exchange that eventually ensued proved a pilot project, breaking new ground and exceeding the traditional scope of regular Erasmus-funded projects – which last up to two weeks rather than a whole academic year. New administrative frameworks were accordingly called for. The International Office at the University of Hamburg generously supplied a model cooperation agreement for the two institutions. Work on implementing the exchange began in 2019, with the HR and legal departments at each institution drawing up various drafts of the agreement and sending them back and forth between Turku and Hamburg. Issues to resolve included agreeing upon teaching loads to be undertaken at each host institution, acquiring the necessary health, occupational accident and liability insurance, clarifying intellectual property rights, and setting out terms for maintenance of the participants’ existing employment statuses at their home institutions. The host institutions, to the extent of their capabilities, were to provide practical (rather than financial) assistance to the participants in finding accommodation. The cost of travel between the two institutions was, in principle, the responsibility of the participants. This notwithstanding, HAW Hamburg’s Faculty of Engineering and Computer Science and its International Office joined forces to reimburse Andreas Baumgart, who moved to Finland with his family for the year, for his removal expenses, and Patric Granholm received support from Turku UAS for travel expenses to Hamburg.

PERSONAL IMPRESSIONS AND NOTES FROM THE EXCHANGE

Big or Small

Turku is a small city, not a metropolis on the scale of Hamburg or other major European cities. The decision to go for "small", to move from Hamburg to Turku, stemmed from our desire for our children to explore their area independently. Notwithstanding my awareness of Turku's relative size, I had hoped and expected to find an active cultural life in my new temporary home, including art exhibitions, concerts, and interesting restaurants. Indeed, I am certain this is all to be found here under normal circumstances, but, regrettably, the COVID-19 restrictions had closed everything down. Instead, I enjoyed pleasant cycle routes and outdoor activities in nature reserves outside the city center.

Education

The teacher of one of my daughters in Turku told me: "I think that in Finland, teachers kind of stand behind their pupils: they coach them, they see to it that each stays tuned – [including] in difficult phases - and cares for their development. Teachers in Germany seem to be more of manager[s]: standing in front of the pupils, marking the targets and giving instructions." We noticed that in Turku, our daughters developed deeper and emotionally more attached relationships with their teachers than they had with their teachers back in Germany. This highly positive observation causes me to wonder whether the same is true in higher education. A further difference from Germany that I noted was the extent of provision of technology – PCs and iPads - to secondary school students, which ensured that they had the hardware required to switch easily to distance learning during COVID-19.

Responsiveness, good faith, and a little help

The signed confirmation letter that gave the exchange the go-ahead arrived on the very morning that I left with my family to catch the ferry to Helsinki. This initial lesson in flexibility and responsiveness to an evolving situation has been succeeded by numerous others during the course of the exchange, not every part of which was planned down to the last detail; much took place in good faith that both parties would find ways to handle any challenges that presented themselves. The support of both institutions' executive boards proved crucial in overcoming last-minute hurdles. Both Turku UAS's Rector and President Vesa Taatila and HAW Hamburg's President Micha Teuscher personally went out of their way to make this exchange happen.

CONCLUSION: NEW BEGINNINGS IN UNSETTLING TIMES

Every long-term stay abroad divides life into a "before" and an "after". It changes the way we perceive and value things in our professional and personal lives. As the German writer Hermann Hesse put it: "*Jedem Anfang wohnt ein Zauber inne*" -- there is a magic inherent in every beginning. This particular beginning, planned long in advance and supported with great commitment by our respective institutions, happened to coincide with COVID-19, with concomitant impact on both our personal and professional experiences during the exchange. In the pandemic's second wave, students and teachers had acquired greater routine in managing the ongoing limitations, but were beginning to tire of them. We lecturers faced teaching environments markedly different from the previous norm. While Turku AMK was delivering lectures face-to-face at least at the beginning of the autumn semester, HAW

Hamburg had closed down completely. Turku AMK has a new open lounge, where many teachers met and continue to meet regularly over lunch or a cup of coffee; HAW Hamburg offered no such casual get-together spaces at this time. We thus found ourselves with highly unequal opportunities for face-to-face discussion and networking. Pandemic aside, the general level of collaboration between lecturers seems to differ in the two countries: while in Finland the exchange lecturer was frequently involved in cross-departmental matters such as organizing workshops for Erasmus students or acting as a visiting evaluator in student group meetings, this does not appear to be common practice in Hamburg.

Despite all difficult circumstances and cultural differences surrounding the experience, the exchange detailed in this paper represents a very practical example of faculty development in line with CDIO principles. It provided two HE teachers with a specific opportunity to reflect on their teaching and their ongoing learning in a new context. The length of the exchange made it possible for the participants to understand higher education in another country in a way that would not have been accessible to them from the traditional, very short type of exchange experience. Alongside its influence on the perceptions of teaching and learning held by those involved, the exchange has opened up valuable insights and new points of view at both participating institutions and among their faculty. What is likewise beyond doubt is the highly positive nature of our personal experiences in our host countries, notwithstanding the Covid-induced limits on cultural activities. Once the initial excitement had abated and a routine had gradually set in, we began to discover that features of our daily lives at “home” that we had taken for granted are not such fixtures everywhere. It is this more profound understanding of “culture” and its elusive essence that we believe can only emerge from a longer period of exchange than is currently typical. On this note, we will conclude by expressing our hope that this paper might inspire fellow teaching staff in HE to take the initiative and venture into the unknown. And we hope it will encourage institutions to take a broader and above all longer view on internationalization and mobility, encompassing staff – teaching and non-teaching alike - alongside students and promoting the benefits of a longer-term exchange experience. We hope this paper may inspire fellow teaching staff in HE to take the initiative and venture into the unknown. And we hope it will encourage institutions to extend their view on internationalization and mobility to encompass staff – teaching and non-teaching alike - alongside students.

To close, we would like to extend a special thank you to Katherine Ebisch-Burton for her outstanding editing support while writing this paper.

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BIOGRAPHICAL INFORMATION

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DESIGNING A NEW INDUSTRY-RELATED SPECIALIZATION IN ELECTRONIC SYSTEMS DESIGN

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ABSTRACT

Preparing students for real-life challenges is one of the crucial goals of engineering education. Nevertheless, gaining practical, industrial experience takes time and effort that usually lays beyond the classical curricular activities. This paper describes our approach, which promotes cooperation between academia and industrial partners to the benefit of both. Although the case described has been implemented while developing a new specialization at the master study program of Electronic Systems Design at Norwegian University of Science and Technology, the applied methods can be implemented in other programs. The key concept is to provide students with industrial projects to work on for the whole 2-year study period. The course portfolio is then individually chosen by every student to the benefit of project execution, which results in tailored skill profiles unique for every student matching the competence profiles sought by our industrial partners. Our partners have an active, formative role in the process of course choice and function as industrial supervisors of project work, thus the students effectively have access to both industrial and academic supervision. Gaining practical experience early during the project activities likely ensures a deeper understanding of the project-related challenges during the next semesters, resulting in a higher quality of the final delivery – the master thesis. After finishing the two-year practical project work, our students become more qualified for further cooperation with the partner company. To evaluate our approach, we have performed a student survey as well as collected feedback from our industrial partners. The results of the evaluation are presented and analyzed. Necessary adjustments to the implementation of the proposed scheme due to the COVID-19 outbreak are also addressed. Finally, the paper presents links to digital resources that provide more detailed information about the organization of the specialization that can be reused in similar cases.

KEYWORDS

Industry engagement, Workplace and community integration, Workplace learning, Engineering entrepreneurship, Standards: 1, 2, 3, 5, 7, 8, 11,

INTRODUCTION

In 2016, Norwegian University of Science and Technology (NTNU) merged with the University Colleges of Sør-Trøndelag, Ålesund, and Gjøvik to form Norway's largest university. The merger resulted in many administrative and educational changes, thus opened the possibility of designing a new industry-related specialization at the Electronic System Design study program. Although the merger resulted in a plethora of options regarding design opportunities around the new specialization, we wished to maintain the tradition of tight cooperation with local industry partners that used to be a signature of our former University College of Sør-Trøndelag (UCST). An example of such collaboration was the cooperation with the industrial cluster Norwegian Center of Expertise Instrumentation. This paper presents our proposal and first experiences in creating a win-win situation for all three involved parties: academia, industry, and students. In the first part of the paper, we describe a project-centric design of our specialization and the course structure that supports core and optional CDIO standards, while the second part of the paper describes the practical implementation of cooperation and teaching processes. The third part of the paper presents the evaluation of the proposed solutions and discussion regarding possible future enhancements and adjustments necessary due to the COVID-19 pandemic.

The necessity of incorporating CDIO standards was one of the conclusions of a recent internal NTNU report titled Sustainable Competence (Øien et al., 2020) which results from the project Technology studies of the future lead by Geir Øien (Fremtidens Teknologistudier - NTNU, 2020). Also our colleagues at the Department of Electronic Systems Design at NTNU have long experience of using the CDIO approach in teaching, which resulted in many exciting projects, including the engineering ladder (Lundheim et al., 2015) and introducing problem-based learning for the first-year students (Bolstad et al., 2020). Inspired by their previous work and our experience with cooperation with industrial partners at UCST, we decided to design a CDIO based approach during the later study years, especially in the master program. Besides the core CDIO standards (Malmqvist, Edström, & Rosén, 2020), we wished to partly address the emerging optional CDIO standards (Malmqvist, Edström, Rosén, et al., 2020) in the process of specialization design that are of vital importance for understanding the broader context of engineering work. As we observed in the previous years, many students working on their master projects acquired a deep understanding of the challenges connected to their projects towards the end of the project semester. However, early exposure to real-life engineering problems and context-related knowledge accumulation is likely to produce better end results derived from a deep understanding of the engineering challenges (Martins et al., 2019). Therefore, we decided to set the project work as a central piece of our new specialization. This way of organizing the specialization allows students to iteratively work in the Conceive – Design – Implement – Operate regime on real-life projects. The students actively learn by being responsible for their part of the project activities and receiving feedback from academic and industrial supervisors. It is worth mentioning that the same framework can be used in a research-based project by switching industrial partners with research actors.

SPECIALIZATION DESIGN

While designing the course plan for the Smart Sensor Systems (3S) specialization, we wanted to ensure that besides gaining experience via project work, every graduate will also acquire knowledge related to innovation and entrepreneurship. Therefore, the course plan was divided into four distinctive parts (Table1). The first part is the project work represented by the green color. Please note that the amount of project work gradually increases during the study time, starting from one 7.5 ECTS point course during the first semester ending at a full-time project work during the master semester. The main goal here is to allow students to conceive, design, and implement their systems' first iteration during the early months of the project work. The second important part consists of core engineering and elective courses represented by blue and grey color in Table 1. The students can individually choose these courses based on their significance for the project work. Finally, the last part of the plan is related to innovation and entrepreneurship. The students start with a course in design thinking to get used to thinking about the end-user of their system. Then the course Experts in Teamwork prepares them to cooperate with colleagues from very different backgrounds. Finally, more business-oriented courses in the third semester ought to give them an understanding of the administrative and financial part of the process of designing electronic systems. Although the courses mentioned in the last part of the portfolio are of an introductory level, they will provide students with the necessary conceptual apparatus that will aid them while communicating with their business partners.

Table 1. The course plan of the Smart Sensor Systems specialization
(O) – Compulsory course; (VA) – Elective course – Coordinated in teaching and examination schedules; (V) - Elective course; (M1A) – At least one course from group A

<table>
<tr><th colspan="6">Course plan</th></tr>
<tr><td rowspan="2">2nd year</td><td>Spring</td><td colspan="4">TFE4930 - Electronic Systems Design, Master’s Thesis</td></tr>
<tr><td>Autumn</td><td colspan="2">TFE4580 - Electronic Systems Design and Innovation, Specialization Project (O)</td><td>TFE4595 - Electronic Systems Design, Specialization Course (O)</td><td>TIØ5200 - Project Organizations (VA)
TIØ4146 - Finance for Science and Technology Students (VA)</td></tr>
<tr><td rowspan="2">1st year</td><td>Spring</td><td>TFE4204 - Sensor Systems Design II (O)</td><td>Elective (V) – from all NTNU courses</td><td>TTK4145 - Real-time programming (VA)
TTM4115 - Design of Communicating Systems (VA)</td><td>Experts in Teamwork (O)</td></tr>
<tr><td>Autumn</td><td>TFE4202 - Sensor Systems Design I (O)</td><td>Elective (V) – from all NTNU courses
TTT4120 - Digital Signal Processing (VA)</td><td>TDT4258 - Low-Level Programming (VA)
TTK4155 - Embedded and Industrial Computer Systems Design (VA)</td><td>TPD4142 - Design thinking (M1A)
TMM4220 – Innovation by Design Thinking (M1A)</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="2"></td><td>Project</td><td>Elective courses</td><td>Programming/ Electronics</td><td>Entrepreneur/ Innovation</td></tr>
</table>

As a result, our graduates will not only have a tailored course profile for their project work, they will also have a basic understanding of the functioning of the whole company environment around the project.

Dedicated courses

Let us briefly describe the design considerations around the two introductory project courses: Sensor Systems Design 1 (SSD1) and Sensor Systems Design 2 (SSD2). These courses are reflecting the CDIO principle of system development and provide a playground for introductory project work. Course descriptions have been developed according to the National qualifications framework for lifelong learning (NOKUT, 2011). In short, the delivery of the SSD1 course aims at being a “first working prototype” that is far from optimal, but that will enable students to make all necessary introductory errors and concentrate on understanding the project task, while SSD2 course aims at optimization of the chosen features of the system. Course descriptions has been designed in a way that is general enough to cover a wide variety of possible projects, however, at the same time reflect the best engineering practices of CDIO standards. We decided to use an IEEE conference paper template as a report template (IEEE, 2020). This teaches students how to use a standardized research template and makes the evaluation of the project work easier. The detailed description of Sensor Systems Design courses including content, learning outcome and evaluation can be found on NTNU course pages(Course - Sensor Systems Design 1 - TFE4202 - NTNU, 2020), (Course - Sensor Systems Design 2 - TFE4204 - NTNU, 2020).

After finishing the first year of studies, students continue to work on their projects, but since they build on the knowledge and experience acquired during the first year, they are able to effectively use it to the benefit of their project work. This happens during the course: Electronic Systems Design and Innovation, Specialization Project that is of 15 ECTS points. At the same time, they acquire specialized knowledge through the Electronic Systems Design, Specialization Course that offers 18 modules that students can choose from. After one and a half years of working on a specific project, students start the master thesis. Since the whole cycle has not been finished yet, we cannot evaluate the increase in the quality of master thesis deliveries.

PRACTICAL ORGANIZATION

Due to the involvement of many actors, the practical organization of activities necessary to create an environment that fosters cooperation is far from trivial. It was therefore, our priority to set up effective communication schemes that would allow the identification of win-win cooperation possibilities. Although we find working with the 3S specialization very inspiring, it is fair to say that there is a significant part related to the organization of the startup events and the coordination of the whole process with our industrial partners. It is worth mentioning that the whole process is conducted as informally as possible to reduce the communication threshold between parties. The details of the process are presented in interactive diagrams that describe the activities during the first and the second year of study. These diagrams that are available here: link1 and link2 are used for conveying the information to both students and industrial partners and work as a process guide.

Invitations and one-pagers

The first step in the process is sending e-mail invitations to our industrial partners that contain a one-pager – the PowerPoint template, that is accessible via link3 that will be used by our partners to prepare short descriptions of their project proposals. The one-pager contains necessary contact information for our partner, a brief description of the proposed project task, current project status, and descriptions of the skills essential for completing the project. Collected one-pagers are shared with the students, so they could make a preliminary evaluation of the projects that seem to be attractive to them.

Kick-off conference

The next step is organizing a kick-off conference where our industrial partners present their project proposals, and students get the opportunity to directly communicate with the partners to learn more about the project proposals as well as about partner companies and their expectations. Every company gets only five minutes to present their proposal (and we call this stage "fast and furious" way of presenting). This ensures that only the most important information connected to the project is presented and makes the conference possible to digest for all parties. After five, 5-minute-long presentations, we relocate our partners to their individual meeting rooms, where students who are interested in their project proposals can ask follow-up questions and discuss details regarding projects. To sum up, every slot contains five presentations and a half an hour for discussions between companies and students, which can be performed in one hour.

Figure 1. Kick-off conference presentations

Project choice

After the kick-off conference, students have approximately one week to decide which project to choose. From this moment, students take over the communication with companies and are responsible for the next administrative steps that involve coordination of contract signing and health and safety analysis of their projects. They are also responsible for consulting industrial supervisors to choose an optimal course portfolio.

Peer reviews

During SSD1 and SSD2 courses, students are obligated to perform three peer reviews, which are individual meetings with their peers to discuss the project work. Their role is to act as "critical friend" (Biggs & Tang, 2011) and carefully listen and comment on the issues presented by their peer. Students have the freedom to decide where and when such peer review will take place as long as it is performed before the deadline. The only requirement is to choose a different person every time. We only evaluate if the peer review is performed by checking an online peer review table filled by the students. Peer reviews function as an informal arena to discuss project issues. One could think of them as a special version of an inverted classroom, with the fundamental difference that the classroom is interchanged with a single person, and the presentation is interchanged with a friendly but substantive discussion. In contrast to an inverted classroom approach, having only two people in the conversation ensures the full attention of both persons involved. The last, third peer review revolves around the submission of the project reports. Students are encouraged to read their peer's reports and point out places that are difficult to understand. The expected results of peer reviews are: creating a better group environment, enhancing learning through discussions.

3S Specialization wiki pages

To ensure effective information flow, we have developed a dedicated wiki-based platform where students can find instructions, course reviews, report guidelines, a student knowledge base, and a student forum.

EXPERIENCES

Although the students who enrolled in our new specialization have not finished the whole educational cycle yet, we collected feedback from involved parties to ensure formative influence on current activities.

Student surveys

To evaluate how students experience our new approach, we have performed two surveys. The data for the first survey has been collected from 10 students after finishing the first semester of the 3S study.

Figure 2. Diverging stacked bars chart illustrating students' responses after the 1st semester

In Figure 2, we represent survey results as a coordinated set of diverging stacked bars chart. Each student answered 25 questions on the five-level Likert scale survey. These questions can be categorized into four different groups. The first (Q1-Q6) and the second (Q7-Q10) group includes the questions that aim to measure the satisfaction level of the students about how useful the course was to improve their practical/theoretical skills and how the course helped them to learn new skills, respectively. The third (Q11-Q21) set of questions implies the student's satisfaction at each stage of the 3S structure, while the fourth (Q22-Q25) set represents the student's engagement in 3S program compared to other courses. The diverging stacked bars chart in Figure 2 is completely deviated to the right side, which shows that students are satisfied in all groups of questions.

Figure 3 presents results from the second survey performed at the end of the second semester. Data has been collected from eight students. Note that not all questions are similar to the first survey. The overall student evaluation of the specialization and their progress is positive, however the COVID-19 pandemic contributed to the critical evaluation of the amount of contact between teachers and students. This issue has been addressed immediately after this information has been collected.

Figure 3. Diverging stacked bars chart illustrating students' responses after the 2nd semester

Feedback from industry

After the first invitation round, we received spontaneous, positive feedback from our industrial partners that emphasized the need for practical cooperation between industry and academia. The general viewpoint can be illustrated by this quote from a Head of Sensor Technology at one of our partner companies:

> *"The study looks great! I showed the program to the group, and we thought that here are courses we should have taken :-)"*

We list more quotes that indicate the need for cooperation between academia and industry.

> *"This is very interesting for our company [...] which develops and commercializes industrially certified sensors (IoT)"*

> *"Very interesting study specialization you open for. Here is a project proposal from us that we hope can capture the interest of the students."*

> *"This sounds exciting. Is this something you plan to implement permanently every year in the future? Do you know if there are other fields of study at NTNU that have a similar implementation of projects in collaboration with the industry?"*

We have also collected informal feedback by telephone conversations with our industrial partners after every semester. All feedback was positive.

Adjustments and adaptations to COVID-19

The black swan event embodied by the pandemic influenced our specialization by an inability to recruit international students. Furthermore, due to the more unpredictable future, many companies had to adjust their plans and focus on core activities. This resulted in a lower number of project proposals.

The necessary adjustments were implemented by moving the whole communication process, including the Kick-off conference, to the virtual realm. Although building a rapport between all involved parties is much more challenging without direct contact and a possibility to have a chat at the coffee table, we were able to partially recreate the friendly atmosphere necessary for establishing trust and open dialog. Another issue that needed to be addressed was the fact that students in our specialization mainly work independently on their projects. Since the campus was inaccessible to them, it was challenging to provide the necessary supervision and social background for student activities. This issue has been addressed with the newly recruited group of students by organizing weekly online update meetings. During these informal meetings, every student briefly presents no more than three main activities from the past week and no more than three main tasks for further work in the following week. Students are encouraged to actively participate during the meetings by asking questions and making suggestions regarding possible enhancements in their peers' projects. All students signalized that these short, informal sessions are valuable both for interpersonal contacts and for their project development.

CONCLUSIONS

We have successfully designed, implemented, and initially evaluated a new specialization in Electronic System Design by applying several cores and optional CDIO standards. Considering the positive feedback from a limited number of industrial and student stakeholders, we conclude that the proposed approach may have some advantages that could be transferred to implementations outside electronic design specializations. However, the proposed individualized approach brings challenges connected to student group formation, synchronization of the course schedules and extended supervision. These challenges were even more highlighted during the COVID-19 outbreak. Therefore, it was advisable to implement solutions ensuring regular contacts between classmates and teachers that have been realized in the form of brief weekly update meetings.

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IMPLEMENTATION AND EVALUATION OF A NEW PBL ASSESSMENT MECHANISM

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ABSTRACT

Professional engineering practice requires both technical and transversal skills, which raises the need to create modern learning methods that develop both. In alliance with CDIO, Problem Based Learning (PBL) has emerged as an effective way of learning and teaching since it fosters the enhancement of transversal competences along with the required technical ones. Moreover, PBL employs real world problems as a learning tool and encourages students to learn independently while being supported by academic facilitators. In PBL approaches, the assessment process is one of the common issues pointed out by students and faculty since it should not only assess technical knowledge, but also transversal competences. Therefore, various academic institutions have developed different assessments tools and mechanisms. However, whereas such tools work in a given learning environment, the social, technical, pedagogical, and other aspects make of its implementation in other environments a challenge. This paper presents the design and implementation of a new assessment framework to evaluate the student work within PBL courses. It addresses new techniques to measure the individual student's contribution while he/she is working in a team to solve a real-life problem. Instead of the previously implemented assessment mechanism that involves only one mid-term and one final assessment, the new assessment mechanism suggests several individual and group sub-assessment tools distributed along the semester. The outcome of this new assessment framework is evaluated and compared to the previously implemented PBL assessment framework.

KEYWORDS

Project Based Learning, Engineering Education, Assessment, Standards 5, 6, 7, 8, 11.

INTRODUCTION AND LITERATURE REVIEW

Project Based Learning

The rapidly expanding knowledge base in different subjects necessitated the presence of a way for dealing with the enormous amount of knowledge. Project Based Learning (PBL) effectively shifted emphasis away from just collecting and absorbing amounts of knowledge to enabling the students to learn effectively and independently. PBL is a student-centered educational method which aims to build problem-solving skills through self-learning and promote sustainable learning and teamwork skills. In the PBL process, learning is initiated by and structured around complex problems rooted in situations that the learner is likely to encounter in the real world outside of school (Woods, 1985). It is a modern learning strategy that first originated in the 1950s at the medical school at Case Western Reserve University. Then, in the 1960s, McMaster University in Canada introduced it. It was initially introduced as a method of educating physicians to apply their knowledge in the perspective of real patient health problems (Barrows & Tamblyn, 1980) and (Boud & Feletti, 1998).

In a PBL context, a real-life project usually suggested by or related to the industry is given to the students who take the main role of addressing its various problems and build a solution for it from the conceive stage till the last stage of operating it successfully as per the CDIO cycle. Compared to traditional lecture-based learning, PBL has many advantages such as student-independence and self-confidence, increased motivation in the learning process and finding solutions for real-world projects in an educational environment (Powell & Weenk, 2003; Graaff & Kolmos, 2007; Moreira et al., 2011; Fernandes, 2014). PBL is believed to motivate, teach clinical reasoning; store relevant information in an integrated way, and in the way it will be retrieved and applied; tie learned information to a vivid experience. Thus, it plays an important role in helping long term memory, facilitating recall and the transfer of that information to future related problems; reducing the overload of nonrelevant factual material; and promoting self- and peer-assessment and life-long self-learning skills. All these are accomplished in an active, interactive and satisfying way (Willem et al., 1985). So, self- and peer-assessment skills are among the skills encouraged by PBL, although the PBL curriculum does not guarantee the appropriate development of such skills (Langendyk, 2006).

Assessments Mechanism

The major challenge for PBL implementation is in the applied assessment strategy. Many institutions around the world still face challenges in developing the right assessment tools for the right group of students. The fundamental reason for this challenge is due to the lack of academics with the right skills and commitments. In PBL, tutors' role is different from the role of a teacher in a traditional and didactic teaching setting as per (Addae et al., 2017). Indeed, human factors such as personal bias, errors/ effects such as leniency effect, stringency effect, central tendency error, logical error, and halo effect may affect tutors' rating of students in PBL (Zahid et al., 2016). PBL delivery requires extra effort from the academics in ensuring students learn the desired knowledge within the specified time. In most cases, academics do not receive the training when they join a new institute which promote PBL mode of delivery. It is important to understand various proven assessment strategies and adopt those in PBL subjects. Tai et al. (2007) reported various categories on assessment strategies. According to them, content deals with the knowledge students acquire, while process focuses on the students' ability to apply knowledge and skills in problem-solving. Outcome assessments should involve the products students design and evaluate their combination of content and new applications of knowledge. Tai et al. (2007) also shared that PBL tends to require more of a focus on assessing the process than on assessing the content, yet obviously content knowledge is still important. Ultimately, we need to seek evidence that students possess the means to embrace situations faced by practitioners of their profession and are competent to know how to go about dealing with such situations. White (2001) talks in terms of rather than assessing the achievement of content-oriented objectives, we need to assess achievement of process-oriented objectives - those that relate to how practitioners of a discipline or profession think about and solve problems within a certain field. The success of delivering effective PBL subjects starts with the development of the right assessment items for the relevant subjects. This paper presents some of practical experiences of the authors in developing and delivering the various PBL based subjects and assessments in the area of power systems.

At the Australian College of Kuwait (ACK), the students are exposed to PBL since their second year of study in all engineering disciplines it offers. It revealed a positive result in terms of improving student learning, motivation and graduate attributes (Alameen et al., 2019). In PBL-based courses at ACK, students work together in teams of 4 to 5 members, to solve a real-life scenario, which require the application of contents of many courses offered in the same or previous semesters of their study plan and/or self-learn to acquire new knowledge required to address the project requirements. The implementation of PBL at ACK is also aligned with the CDIO process as students are required to conceive, design, implement and fully operate a solution for the project and are assessed accordingly.

Initially, the assessment of the teamwork was carried out twice per semester and was based on assessing each learning outcome of the PBL course separately and for each student according to a detailed criteria sheet that lists the required criteria for each level of accomplishment of each learning outcome. Those are collected from various assessment tools submitted by the students such as workbook, final report, peer and self-evaluation sheets. However, many concerns were raised by students and faculty members and both requested a more detailed and comprehensive assessment mechanism that simplifies the assessment process and fully recognize the individual contribution of each team member. Therefore, in alignment with the 11th standard of CDIO, several meetings were conducted between all involved PBL facilitators to share their experience on the most effective assessment mechanism. Students also contributed throughout their feedback to PBL facilitators.

In what follows, the design and implementation of a new assessment framework to better evaluate the students' work within PBL courses in ACK is presented. New techniques to measure the individual student's contribution while he/she is working in a team to solve a real-life problem are addressed. The new assessment framework is based on creating several individual and group assessment tools distributed along the semester to provide continuous feedback to students and smoothen the evaluation process.

PREVIOUS VS NEW ASSESSMENT MECHANISM

It is important that academic courses and programs are revised to suit the industry revolution. Accordingly, in the Australian College of Kuwait we have recently started curriculum review. Being involved in the curriculum review process for several subjects, it was found that developing the right assessment items is extremely vital in ensuring the students acquire the right skills and knowledge. Previous PBL assessment mechanism was based on two assessments as shown in Table 1. The midterm portfolio was taking place at the middle of the semester and consists of two elements, course portfolio and presentation (known as viva voce). Whereas the course portfolio groups the required evaluation tools and documents (workbook, self and peer assessment sheets, simulation files, etc.), the viva voce is dedicated to measure the level of understanding of the knowledge provided in the submitted portfolio in addition to the other soft-skills such as presentation, stress management, etc.

The first midterm assessment weights 30% and aims at providing an initial feedback on the overall students' performance and ways to improve their overall standing in the PBL course. Another similar yet more summative assessment which weights 70% is conducted at the end of the semester. This assessment evaluates the improvements achieved by the students after the first assessment and the overall achievement in each of the PBL course's learning outcomes.

Table 1. Initial Assessment Mechanism (Applied to all PBL courses)

Assessment No. and title	Method of Assessment	Learning Outcomes/ Performance Criteria Covered	Week	Weight
Assignment 1 Midterm portfolio	Course Portfolio	LO1 – LO9	1-7	30%
	Viva Voce		7	
Assignment 2 Final portfolio	Course Portfolio	LO1 – LO9	7-13	70%
	Viva Voce		14-16	

Table 2. Current Assessment Mechanism (Example: Embedded Operating System Course)

Assessment No. and title	Assessment tool	Individual (I) / Group Work (G)	Learning Outcomes Covered	Week	Weight	Total weight
Assessment 1: First Evaluation	Progress report	G	LO1-9	4-6	10%	10%
Assessment 2: Second Evaluation	Technical Evaluation	I	LO1-9	7	10%	20%
	Presentation	I / G		8	10%	
Assessment 3: Third Evaluation	Technical evaluation	I	LO1-9	7-14	15%	30%
	Final Presentation	I / G		7-14	15%	
Assessment 4: Final Evaluation	Workbook	I	LO1-9	14	20%	40%
	Final Report	G		14	10%	
	Final code Hardware prototype	I / G		15	10%	

The new assessment mechanism consists of four main assessments distributed over the semester where each one covers all course learning outcomes as shown in Table 2. Each assessment is then divided into sub-assessments tools based on the nature of the course. The first two assessments are conducted in the first eight weeks of the semester to provide an early intensive feedback to the students with an overall weight of 30%. The third and the fourth assessments cover the second half of the semester. As an example, the Embedded Operating System course as shown in Table 2, has eight sub-assessment tools that measure all technical and transversal skills that are required by professional engineering practice. Unlike the previous PBL assessment mechanism, each sub-assessment tool may assess one or more of the course learning outcomes.

To promote teamwork while keeping the significance of individual contributions, grades are distributed equally between individual and group work. As an example, part of the presentation assessment grade is awarded the same for all group members (such as the presentation file, the organization, time respect, etc.) whereas the other part of the grade is awarded individually (oral presentation, questions and answers, stress management, etc.).

NEW ASSESSMENT MECHANISM EVALUATION

To evaluate and compare the two assessment approaches, data were collected via several meetings that were conducted with the involved PBL facilitators to share their experience and comments on the most effective assessment mechanism. Students also contributed by answering a well detailed self-administered questionnaire (survey). It is a descriptive study that has been performed on a random sample of students in Year 4 (n=62) those who are familiar with the old PBL assessment plan and experienced the new assessment framework for their first time. The anonymous survey was administered to the students at the end of the debriefing session of a PBL course to investigate their perception on the overall PBL approach, self- and peer-assessment and the new assessment mechanism. Collected data were coded and entered to a computer and processed using the IBM SPSS v. 22. Descriptive statistics were used, as frequency distribution and comparisons.

Table 3. Survey Participants: Gender and Age

		Gender		
		Male	Female	Total
Age	18-24	14	14	28
	25-34	12	12	24
	35-44	3	7	10
Total		29	33	62

Table 3 presents the age and the gender of the students who participated in the study. Almost half of the students are under 24 where the other half are between 25 and 44 years. Also, females count was slightly higher than males count.

Table 4. Professional Experience, Gender and Age

Professional Experience			Gender			
			Male	Female	Total	
None	Age	18-24	12	13	25	56.4%
		25-34	6	4	10	
1-5 years	Age	18-24	2	1	3	19.3%
		25-34	4	5	9	
6-10 years	Age	25-34	2	3	5	9.6%
		35-44	0	1	1	
More than 10	Age	35-44	3	6	9	14.5%
	Total		29	33	62	100%

Table 4 shows that almost 45% of the participants have professional practical experience. This means that they can better evaluate the PBL approach in terms of teamwork, transversal and organizational skills.

PBL at ACK in General

The survey starts with general questions on the PBL concept to measure the students' perception on this method of education and its application at our college. A very positive feedback was obtained on whether PBL improved transversal, organizational and personnel skills as shown in Figure 1. Indeed, more than 80% of the students agreed that PBL improved their personal and interpersonal skills.

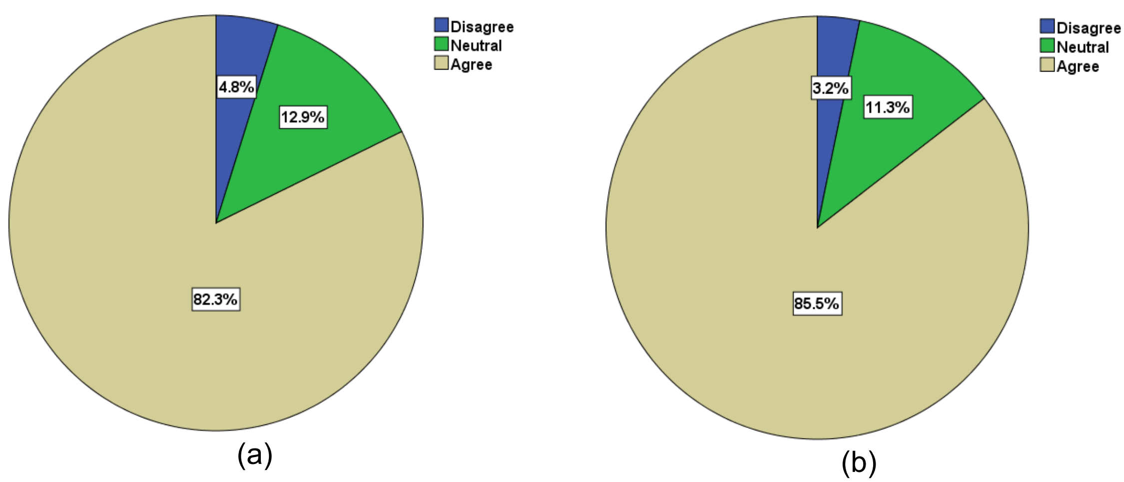

Figure 1. Students' responses to general PBL questions: (a) PBL units helped me improving my transversal skills (e.g. management, leadership, critical thinking, etc.), (b) PBL units helped me improving my personal skills (e.g. communication, creativity, entrepreneurship, etc.).

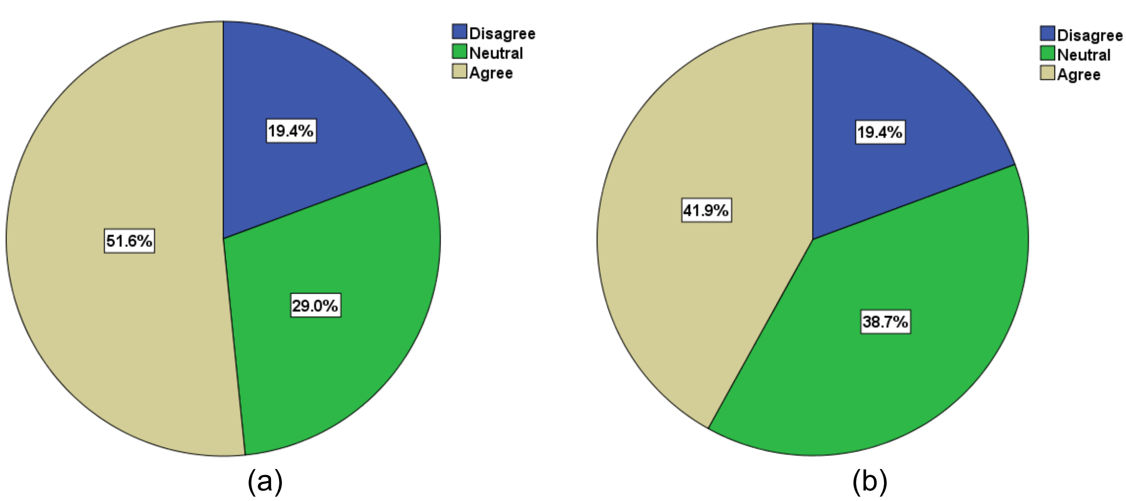

Figure 2. Students' responses regarding peer and self-assessment tools: (a) I am in favour of peer assessments to clarify some points not seen by the instructor, (b) I am in favour of individual grade nomination to clarify some points not seen by the instructor.

As mentioned earlier, the peer assessment is a form each student fills to evaluate the performance of his/her peers in the same group. On the other hand, the self-assessment is another form that each student fills to evaluate him/herself. In both cases, the student should refer to the evaluation criteria sheet and provide evidences. Both documents are submitted by each student confidently to the instructor. As shown in Figure 2.a, almost half of students are in favour of peer assessment to evaluate their group mates. The reason why this response was not high is that the students are avoiding embarrassment and conflicts with their group mates. Moreover, when they do peer-assessment they stress on "overall performance" instead of a detailed proof-based evaluation. On the other hand, Figure 2.b shows that 42% of the students agree on the concept of individual grade nomination, 39% are neutral and 19% disagree with it. The possible reason is mainly the difficulty in evaluating themselves using the criteria sheet or the considerable amount they require to evaluate themselves properly or in the other hand to the possible lack of confidence in their achievements.

New Assessment Mechanism

The second part of the survey is dedicated to evaluating the agreement of the students on the newly implemented PBL assessment mechanism that is based on multiple sub-assessments distributed over the whole semester. As such, the survey questions focused on two main aspects:

- The new assessment framework is improved over the previous one.
- Assessing individual student work within the team is clearly defined in the new PBL assessment plan.

Figure 3.a shows that 61% of the students agree that the new plan has improvement over the previous one as shown. This indicates that the students' understanding of the assessment criteria and grading scheme has improved over the previous criteria-sheet based evaluation.
On the other hand, 67% of the students agree that assessing individual students within a team is better defined in the new assessment plan as shown in Figure 3.b. This suggests that students would better understand the variation of grades between the same group members and would result in less students' complaints and grades appeals.

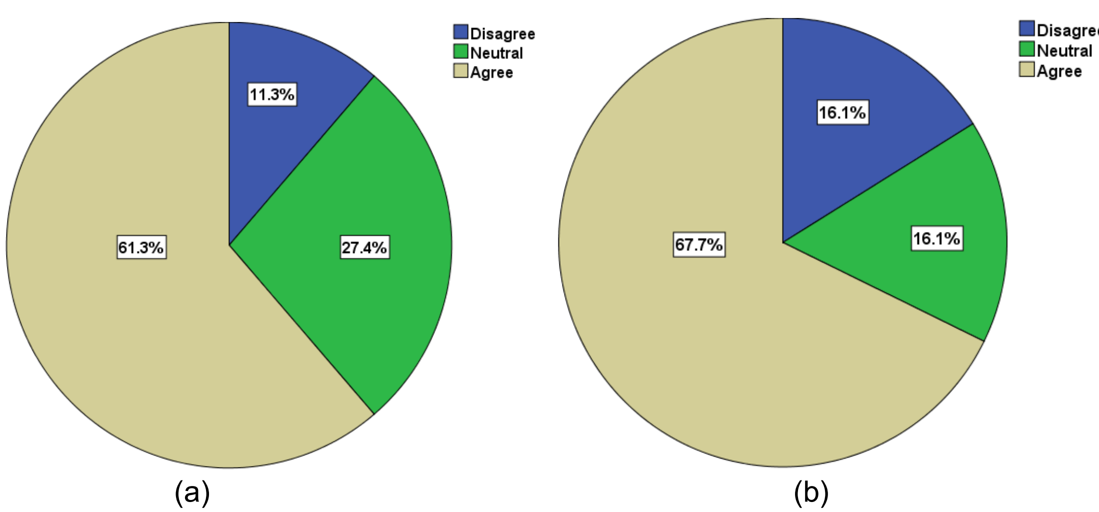

Figure 3. Students' Responses: (a) The new assessment plan is improved over the previous one, (b) Assessing individual student within the team is clearly defined in the new PBL assessment plan

CONCLUSION

In this paper, a new assessment mechanism was designed to enhance the grading process and better evaluate the intended learning outcomes of PBL courses at the Australian College of Kuwait. Instead of the previously implemented assessment mechanism that involves only one mid-term and one final assessment, the new assessment mechanism suggests several individual and group sub-assessment tools distributed along the semester. This new mechanism provides better continuous feedback for the students and help them improving their learning process. The new assessment mechanism is evaluated via a survey that was taken by the involved students who were exposed to the previous assessment mechanism in previous semesters and to the new one in Spring 2019 semester. The results show that students generally agree with the new assessment mechanism which helps them better understanding the grades discrepancy between the same group mates.

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FLIPPED LEARNING ANALYTICS REAL-TIME (FLARET) FRAMEWORK FOR ASSESSING STUDENT LEARNING

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ABSTRACT

In order to inculcate self-directed learning in our students, flipped learning pedagogy can be used in the classroom. The skills of self-directed learning are reflected in 2.4.5 (Self-Awareness, Metacognition and Knowledge Integration) and 2.4.6 (Lifelong Learning and Educating) of the CDIO 2.0 syllabus. Although flipped learning can improve self-direct learning skills in students, it can be difficult for the tutor to monitor all the students in the class with different learning attitudes and speed. In order to assist the tutor in managing a flipped learning class, this paper proposes a Flipped Learning Analysis in Real time (FLARET) Framework to allow a tutor in real time to assess students' self-directed learning readiness and how well they perform during flipped learning lessons. The FLARET Framework aligns with the CDIO Standard 11 which recommends the use of a variety of learning assessment methods to measure the extent to which each student achieves specified learning outcomes. An action research is conducted with the FLARET Framework and the findings from the action research will be presented in this paper.

KEYWORDS

Self-Directed Learning, Flipped Learning, CDIO Syllabus 2.4.5, CDIO Syllabus 2.4.6, Standards: 11

INTRODUCTION

In an OECD educational policy paper (OECD, 2016), it was stressed that there is a need to prepare our students for a volatile, uncertain, complex and ambiguous (VUCA) world. Laukkonen et al. (2018) proposed that meta-learning or self-directed learning, is an important skill that our students need for them to be prepared for the VUCA world. Under the CDIO 2.0 syllabus, self-directed learning is reflected under 2.4.5 (Self-Awareness, Metacognition and Knowledge Integration). Self-directed learning is also reflected under 2.4.6 (Lifelong Learning and Educating). In order to inculcate self-directed learning in our students, flipped learning pedagogy can be used. This paper will describe how flipped learning is introduced to an Environmental Science (ES) module in Singapore Polytechnic.

Flipped learning is a pedagogical approach where traditional classroom-based learning is reversed such that students are given the lecture materials before class. The classroom time is then used to deepen the student's understanding through peer and problem-solving activities facilitated by the tutor. Hence, the process of learning is less directed by the tutor but directed by the students themselves through reflecting on the topic being though and how to apply concepts discussed during the class.

First, this paper starts with a brief overview on flipped learning and how it was introduced into the ES module. Second, the paper will describe the action research and how the FLARET (Flipped Learning Analytics in Real Time) Framework was deployed. The FLARET Framework was developed for real time assessment on how students perform during the author's flipped classroom. Such learning assessment framework, aligns with the CDIO Standard 11 which recommends the use of a variety of learning assessment methods to measure the extent to which each student achieves specified learning outcomes. The benefits and challenges of deploying the FLARET Framework will also be discussed.

FLIPPING ENVIRONMENTAL SCIENCE

The (Environmental Science) ES module was running on a traditional learning framework shown in Figure 1. The ES module is a 60-hour module taught in a semester of 15 weeks. It consist of a 1-hour lecture and 3-hour tutorial session. The learning outcomes are to understanding a) the use of renewable energy technologies, b) the concept of smart buildings, c) the concept of Envelope Thermal Transfer Value (ETTV) in Green Mark, a green building rating tool, d) the design principles for passive and active design strategies, e) the requirements relating to energy optimization through the design of building envelope, f) thermal and visual comfort for building design, g) the principles of air-conditioning systems and h) the design of building systems like plumbing and rainwater drainage. According to Bloom's Taxonomy, traditional learning framework only allows student to attain lower cognitive level of understanding the concepts taught during the in-class lecture. A quiz is given each week on the concepts learnt from the previous lecture before the lecture of a new topic begins. Quizzes help to develop higher cognitive level of applying and analyzing in students. Quizzes test students on their ability to apply what they have understood in the previous lecture and also analyze the problem related to concepts taught in class. However, due to the formatting of the curriculum, lecture time is divided for both quiz and lecture. There is insufficient time for the tutor to discuss the quiz questions in more detail during class. This led to an inability to develop students' ability to apply concepts and analyze problems. The tutorial is an open design consultation session which does not focus on the concepts taught in the lecture.

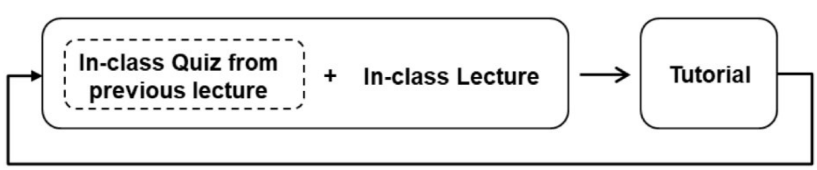

Figure 1. Traditional learning framework for ES module.

To elevate our students' level of mastery over the ES topics, we have chosen to implement flipped learning for the ES lessons in order to convert the in-class time for discussion on how to applying concepts to design problems. The flipped learning framework is shown in Figure 2. Pre-class lesson materials are uploaded on the learning management system, Blackboard, one week before class. The materials are design in the e-learning application, Articulate 360. Students are to read and prepare any questions they would like to clarify in class. The class starts with clarifying any questions on the pre-class materials. It is then followed by 25 minutes quiz. The results of the quiz can be seen real time on Blackboard, questions with high percentage of errors were brought up for discussion with the students to clarify and reinforce learning. The class ends with a survey on the concepts taught. Additional materials are given to students to develop their learning further.

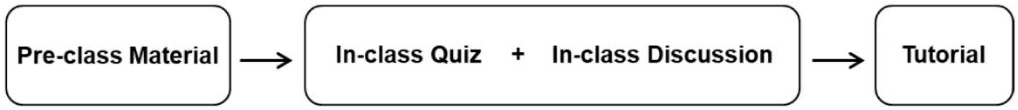

Figure 2. Flipped learning framework for ES module.

Problem Statement of Action Research

As highlighted in CDIO Standard 11, effective learning assessment uses a variety of methods to appropriately assess learning outcomes in students. The purpose of this action research is to tackle 3 learning assessment-related issues while deploying flipped learning. First, the challenge of deploying flipped learning is to manage the varied pace of students' learning. In order to roll out flipped learning lessons successfully, we would need to utilize effective learning assessments to track the level of understanding of the concepts taught in class. Second, we will need to understand the level of readiness in students for self-directed learning. A Learning Preference Assessment can be conducted to determine the Self-Directed Learning Readiness Scale (SDLRS) of each student (Guglielmino, 1978). However, the survey for SDLRS consists of more than sixty questions which will cause survey fatigue in students. Third, the results of the quizzes and surveys that accompanies the flipped learning lessons can take some time to be processed. This did not allow the tutor to quickly address the issues faced by the students in the following lesson time. For flipped learning to be successful, a real time system of collecting and diagnosing the data collected from quizzes and surveys is crucial for us to understand the needs of students and provide faster support for their learning.

Action Research Proposal

As highlighted in CDIO Standard 11, effective learning assessment uses a variety of methods. In the proposed action research, a proposed FLARET Framework shown in Figure 3, proposes the use of the Grit Scale as a self-directed learning readiness assessment and weekly in-class survey in addition to the in-class quiz used in an earlier flipped learning framework shown in Figure 2. The Grit Scale developed by Angela Duckworth (2017) has only 10 survey questions which is fast and easy for students to complete. The use of the Grit Scale as a proxy to the SDLRS, help us to better understand students' self-directed learning readiness in flipped learning and allay survey fatigue due to its short list of questions. Ruttencutter (2018) has shown a very strong and significantly positive relationship between Self-directed learning and Grit Scale. In-class quiz allows the tutor have a quick overview on whether students understand the concepts of the topics taught weekly. The in-class discussion deepens students' understanding in the concept through in-depth discussion on concepts in the lecture material. In-class surveys gets the students to open up on your learning and share any other queries that was not discussed in class.

The proposed FLARET (Flipped Learning Analytics in Real Time) Framework is deployed to address the need of real time feedback from students' quizzes and surveys. The FLARET Framework is based on the Assessing Learning in Real Time (ALERT) Framework (Tan et al. 2019; Yeou 2019) that was developed to monitor students' learning process in real time. The ALERT Framework was developed as a Joint Project by the Learning Analytics Workgroup under the Poly-ITE EdTech Committee. The goal of the framework is to empower tutors to have real time feedback from students after every lesson in order to improve teaching and learning with targeted supported. ALERT was implemented by Tan et al. (2019) for a Global Studies module in Temasek Polytechnic using a Power BI-based dashboard. Power BI is a business analytics software by Microsoft. It provides interactive data visualization and business intelligence capabilities to create reports and dashboards.

Similarly, for this action research, Power BI is used to setup a data visualization dashboard to organize and visualize data collected from quizzes and surveys. Power BI is used as a diagnostic learning analytical tool as part of the FLARET Framework. The data visualization dashboard allows the tutor to have a quick overview on how the students are learning and performing after each flipped learning lesson. The author would like to highlight that the dashboard does not have an automatic feedback for students. The purpose of the dashboard is to assist and provide tutors with a variety of assessment techniques to "*measure the extent to which each student achieves specified learning outcomes*" as stated in CDIO Standard 11. The FLARET Framework is used to monitor students' learning from two flipped learning lesson topics: a) Envelope Thermal Transfer Value (ETTV) and b) Solar Technology for Buildings. The pre-class material, in-class quiz, in-class discussion and in-class survey are specific to the different topics taught weekly. The 10 survey questions for Grit Scale is only done once before the first lesson. The action research was setup with the following research question: what are the benefits and challenges in using the FLARET Framework with Power BI to measure the extent which each student achieves specific learning outcomes in flipped learning lessons stated in CDIO Standard 11?

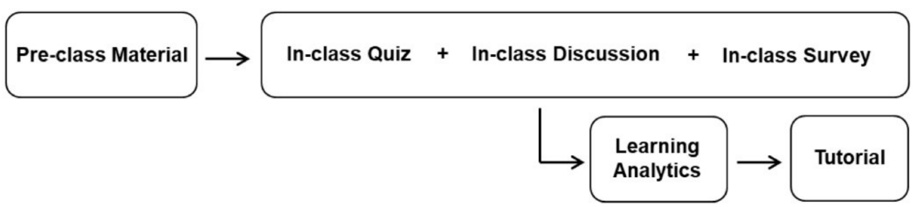

Figure 3. FLARET Framework.

ANALYSIS AND FINDINGS

Having a good overview of the data points is important for detecting anomalies to students' learning. To facilitate a good overview of the data, a Parallel Coordinates Plot (PCP) has been chosen to visualize the dataset collected. A PCP is good for visualizing and comparing multiple features of the samples in a high-dimensional dataset. The PCP of the dataset collected from 2 ES lessons are shown in Figure 4. For confidentiality reasons the students are represented by unique labels, STU_n. The PCP in Figure 4 has the following variables:

Table 1. Description of labels used in action research

Label Name	Description
STU_n	A unique student label representing each student where n = 01, 02 … n, n is the total number of students in the dataset.
Grit	Average of Grit-passion and Grit-perseverance
Grit-passion	Grit score to measure passion
Grit-perseverance	Grit score to measure perseverance
ETTV Quiz	Grade of ETTV Quiz
ETTV Survey	Averaged score of forced Likert Scale for ETTV Survey
Solar Quiz	Grades of Solar Technology Quiz
Solar Survey	Averaged score of forced Likert Scale for Solar Technology Survey

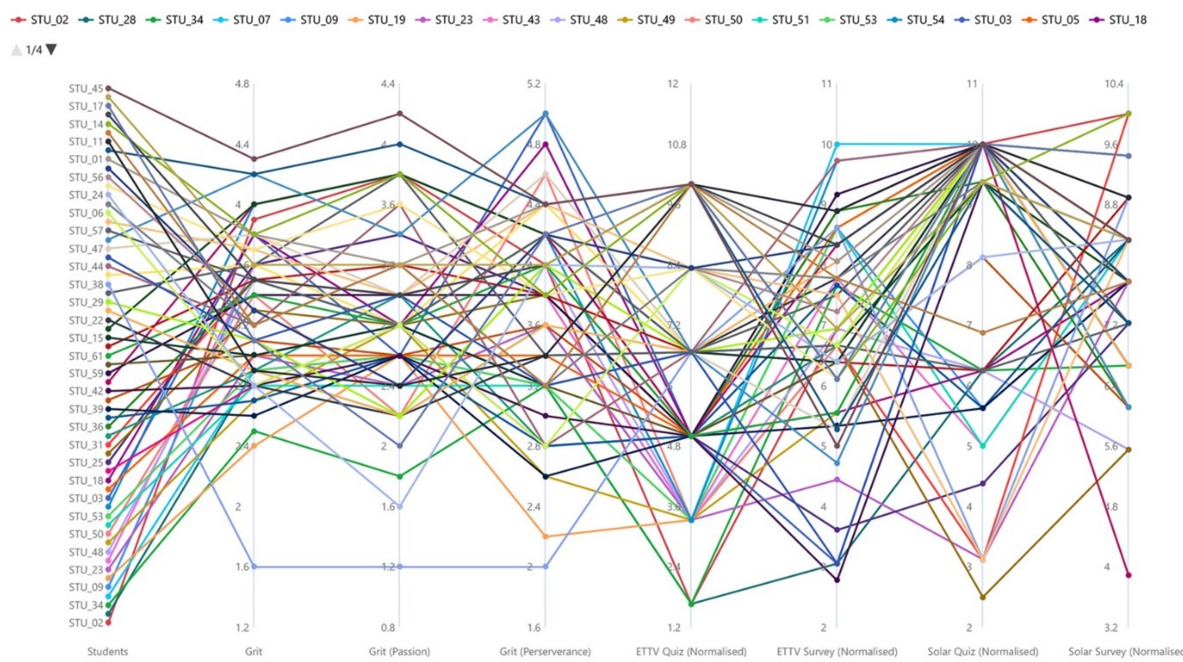

Figure 4. Parallel Coordinates Plot of dataset for 61 students in the ES module.

Grit Scale and Self-Directed Learning

Grit is defined as the passion and perseverance for long term and meaningful goals (Duckworth, 2017). It is how one perceives one's ability to persist in something that one feels passionate about and persevere even when one faces with an obstacle. Grit score of 3 is the midpoint to the 5-point scale of the Grit Scale and based on Duckworth's study, adults with Grit score of 3 is grittier than 20% of the sample population studied by Duckworth. The Grit Scale allowed us to have insights into how students perceived themselves which may affect their self-directed learning ability in flipped learning lessons. The Grit Scale helps to flag up students with potential learning motivation and allows us to pay attention to potential issues of learning. In this action research, Grit score of 3 will be the median point which we set as a minimum Grit score our students should have. Students with Grit score of 3 or less would be seen as not ready for self-directed learning.

From the PCP in Figure 4, what stood out was student STU_38 who has a substantial low Grit score of 1.6 compared to the rest of the students. We were mindful to pay more attention to the student STU_38's learning and encourages him to read the pre-class materials before lessons. To delve deeper into the Grit scores of the students, we could quickly isolate the data of 22 students, in a table with Power BI, shown in Table 2. The ability to isolate and review localized set of samples is useful for tutors to assess students' learning quickly. With reference to Table 2 showing 22 students whose Grit scores are below 3, 36% of them failed one of the two quizzes. At a closer look, although all these students had Grit scores equal or less than 3, only 7 out of the 22 students in Table 2 had Grit-Perseverance scores equal or less than 3. Of these 7 students, 43% failed at least one of the two quizzes. Of the 15 students who had Grit-Perseverance scores more than 3, 33% had at least failed one of the two quizzes. Students STU_23 and STU_28 have the two lowest ETTV survey scores which shows that they have problems understanding the lesson. This finding is also coupled with the fact they have relatively low Grit scores which hints to the fact they have low perseverance and passion to try and figure out the lesson by themselves. Hence, it brings to attention the need for quickly intervene and encourage these students and find out what aspects of the lesson they do not understand and if extra materials or coaching are required in order for them to master the lesson content. Students STU_07, STU_19, STU_34, STU_49, STU_51, STU_53, have Grit scores less than 3 and ETTV survey score of more than 5 but failed their ETTV quiz. For these students, we need to verify if they have misunderstood how to apply these concepts in the ETTV quiz or if they are just not motivated to learn. If they have misunderstood the application of these concepts, more application-based quiz problems can be given to develop their ability to apply those concepts. If it is related to the fact that they are not motivated, these students would require coaching and encouragement to be self-directed learners.

Table 2. Students with Grit score ≤ 3.

No.	Student Tag	Grit – Passion (0 – 5)	Grit – Perseverance (0 – 5)	Grit (Average) (0 – 5)	ETTV Quiz (0 – 10)	Solar Quiz (0 – 10)	Quiz Average (0 – 10)	ETTV Survey (0 – 10)	Solar Survey (0 – 10)	Survey Average (0 – 10)
1	STU_38	1.2	2	1.6	6.7	3.1	4.9	8.6	8.9	8.75
2	STU_19	2.6	2.2	2.4	3.3	9.4	6.35	6.7	7.8	7.25
3	STU_34	1.8	3.2	2.5	1.7	6.3	4	7.7	6.7	7.2
4	STU_39	2.6	2.6	2.6	5.0	5.6	5.3	5.3	7.8	6.55
5	STU_37	2.6	2.8	2.7	5.0	5.6	5.3	7.7	8.3	8
6	STU_49	2.8	2.6	2.7	3.3	10.0	6.65	5.6	6.1	5.85
7	STU_06	2.8	2.8	2.8	8.3	10.0	9.15	6.7	8.3	7.5
8	STU_21	2.8	2.8	2.8	5.0	10.0	7.5	8.9	8.3	8.6
9	STU_22	2.2	3.4	2.8	6.7	10.0	8.35	7.8	9.4	8.6
10	STU_24	1.6	4	2.8	8.3	8.1	8.2	6.4	8.3	7.35
11	STU_42	2.6	3	2.8	5.0	9.4	7.2	2.8	8.3	5.55
12	STU_51	2.4	3.2	2.8	3.3	5.0	4.15	8.6	8.3	8.45
13	STU_07	2.2	3.6	2.9	3.3	10.0	6.65	10.0	6.1	8.05
14	STU_11	2.4	3.4	2.9	10.0	10.0	10	8.9	8.9	8.9
15	STU_26	2.2	3.6	2.9	6.7	10.0	8.35	8.1	6.7	7.4
16	STU_28	2.6	3.2	2.9	1.7	6.3	4	3.1	8.3	5.7
17	STU_33	3	2.8	2.9	5.0	9.4	7.2	6.7	7.2	6.95
18	STU_53	2.6	3.2	2.9	3.3	10.0	6.65	8.6	6.7	7.65
19	STU_05	2.6	3.4	3	5.0	10.0	7.5	8.6	7.8	8.2
20	STU_15	2.8	3.2	3	6.7	10.0	8.35	6.4	6.7	6.55
21	STU_23	2.4	3.6	3	3.3	3.1	3.2	4.4	7.8	6.1
22	STU_60	2.8	3.2	3	5.0	10.0	7.5	6.4	8.3	7.35
	Mean	2.44	3.08	2.76	5.07	8.24	6.66	7.00	7.77	7.39
	Standard Deviation	0.43	0.48	0.30	2.15	2.42	1.83	1.89	0.92	1.02

Table 3. Students with Grit score >3.

No.	Student Tag	Grit – Passion (0 – 5)	Grit – Perseverance (0 – 5)	Grit (Average) (0 – 5)	ETTV Quiz (0 – 10)	Solar Quiz (0 – 10)	Quiz Average (0 – 10)	ETTV Survey (0 – 10)	Solar Survey (0 – 10)	Survey Average (0 – 10)
1	STU_44	3.6	2.8	3.2	6.7	10.0	8.35	9.7	8.3	9
2	STU_46	3	3.2	3.1	6.7	10.0	8.35	3.1	8.9	6
3	STU_12	3.2	3.2	3.2	8.3	9.4	8.85	7.8	7.2	7.5
4	STU_13	3.2	3.2	3.2	10.0	6.9	8.45	7.8	7.8	7.8
5	STU_35	3.8	3.4	3.6	6.7	6.3	6.5	6.7	7.2	6.95
6	STU_41	2.6	3.6	3.1	5.0	8.1	6.55	6.4	6.1	6.25
7	STU_27	2.8	3.8	3.3	5.0	2.5	3.75	6.7	5.6	6.15
8	STU_59	3	3.8	3.4	5.0	10.0	7.5	9.2	6.7	7.95
9	STU_08	3.2	3.8	3.5	6.7	6.3	6.5	6.4	8.9	7.65
10	STU_09	3.4	3.8	3.6	3.3	5.6	4.45	8.6	7.8	8.2
11	STU_25	3.4	3.8	3.6	5.0	4.4	4.7	3.6	7.2	5.4
12	STU_43	3.4	3.8	3.6	3.3	5.0	4.15	7.8	8.3	8.05
13	STU_30	3.6	3.8	3.7	8.3	10.0	9.15	6.1	8.9	7.5
14	STU_14	3.8	3.8	3.8	10.0	9.4	9.7	6.1	10.0	8.05
15	STU_29	2.2	4	3.1	6.7	10.0	8.35	6.9	8.3	7.6
16	STU_16	3	4	3.5	10.0	10.0	10	8.3	8.3	8.3
17	STU_31	3	4	3.5	5.0	3.1	4.05	6.7	10.0	8.35
18	STU_48	3	4	3.5	3.3	6.3	4.8	6.9	5.6	6.25
19	STU_32	3.2	4	3.6	10.0	9.4	9.7	6.9	8.3	7.6
20	STU_02	3.8	4	3.9	1.7	10.0	5.85	6.9	10.0	8.45
21	STU_17	2	4.2	3.1	10.0	10.0	10	6.1	9.4	7.75
22	STU_56	2.4	4.2	3.3	8.3	10.0	9.15	7.2	7.8	7.5
23	STU_58	2.4	4.2	3.3	8.3	10.0	9.15	8.3	7.8	8.05
24	STU_36	2.8	4.2	3.5	5.0	9.4	7.2	8.9	6.1	7.5
25	STU_57	2.8	4.2	3.5	6.7	10.0	8.35	7.5	7.2	7.35
26	STU_20	3.8	4.2	4	6.7	9.4	8.05	6.7	7.8	7.25
27	STU_54	3.8	4.2	4	3.3	10.0	6.65	9.7	7.8	8.75
28	STU_55	3.8	4.2	4	5.0	10.0	7.5	8.3	3.9	6.1
29	STU_40	2.8	4.4	3.6	6.7	10.0	8.35	7.5	8.9	8.2
30	STU_04	3	4.4	3.7	8.3	3.1	5.7	7.5	8.3	7.9
31	STU_01	3.2	4.4	3.8	10.0	10.0	10	8.1	8.3	8.2
32	STU_10	4	4.4	4.2	10.0	9.4	9.7	5.3	7.2	6.25
33	STU_45	4.2	4.4	4.3	10.0	10.0	10	5.0	8.3	6.65
34	STU_50	2.2	4.6	3.4	3.3	10.0	6.65	6.7	8.3	7.5
35	STU_47	3	4.6	3.8	6.7	10.0	8.35	5.3	7.2	6.25
36	STU_18	2.8	4.8	3.8	5.0	6.3	5.65	5.6	7.8	6.7
37	STU_03	2.6	5	3.8	5.0	10.0	7.5	3.1	7.2	5.15
38	STU_52	3.4	5	4.2	6.7	10.0	8.35	4.7	6.1	5.4
	Mean	3.13	4.04	3.58	6.58	8.47	7.53	6.81	7.76	7.29
	Standard Deviation	0.53	0.48	0.32	2.36	2.33	1.86	1.60	1.27	0.98

With reference to Table 3, there are 38 students who have Grit scores more than 3 and the filtered dataset is shown in Table 3. For these 38 students, 23% failed one of the two quizzes. An interesting observation in Table 3, is that 8 students have Grit-Passion scores less than 3 but their Grit-Perseverance scores were greater than 4. These 8 students did not fail their quizzes. In addition, out of these 38 students, 21 students who have Grit-Perseverance scores that are equal or less than 4, 19% of these 21 students failed one of the two quizzes. For the 18 students out of these 39 students who have Grit (Perseverance) scores more than 4, 11% of these 18 students failed one of the two quizzes. Students STU_02, STU_09, STU_43, STU_48, STU_50, STU_54, have Grit scores above 3 and ETTV survey scores above 5. However, they failed their ETTV quiz. These students could be driven individuals but may not have grasped on how to apply the concepts from the ETTV lessons. We have to check with these students if the concepts were clearly understood and set more application-based quiz problems to develop their ability to apply those concepts. In addition, what we can observe from looking at the Grit scores is that students with higher Grit-Perseverance scores are more likely to pass the quizzes. We can postulate that the Grit-Perseverance scores are better indicator that students with higher scores in Grit (Perseverance) are more likely to pass because they are driven to perform well in their coursework.

Quizzes and Surveys

To diagnose students' learning we can look into more details on how they have performed on individual quiz questions shown in Figure 5 and 6, and correlate that with the students' responses to Survey questions. For the stacked column charts for ETTV questions in Figure 8, the group of stacked column charts allowed us to not only see which students failed the quiz but also which questions they did not answered correctly. Looking at the Stacked Column Charts, less students get ETTV questions 4, 5 and 6 correct. These questions are related to the calculation of the ETTV value for the case study given in the quiz. It is a known fact that Architecture students tends to struggle more with applying mathematical equations. Coupling this with students' responses on the individual survey questions shown in Figure 7, we could see that student STU_03 who did not perform well in the ETTV Quiz, disagrees with most of survey questions. The survey questions are shown below:

1. After reading the learning material I had a good overview and understanding of the Green Mark.
2. After reading the learning material I had a good overview and understanding of the ETTV.
3. Having a more focused explanation and discussion on key topics of Green Mark and ETTV during lecture (flipped classroom) is better than a conventional lecture where the tutor only teaches through the presentation slides.
4. Using the time in lecture to work through the ETTV calculation allows you to have a better understanding of the concept of ETTV instead of figuring it out on your own.
5. After finishing class, my understanding of ETTV has improved.
6. After finishing class, my understanding of Green Mark has improved.

Looking at student STU_03's responses to the ETTV Survey, we can tell that as he struggles to understand the topic, it has resulted in him failing the ETTV Quiz. Student STU_03 has a Grit score of 3.8, Grit (Passion) score of 2.6 and a Grit (Perseverance) score of 5 which hints that he has a relative good self-directed learning readiness.

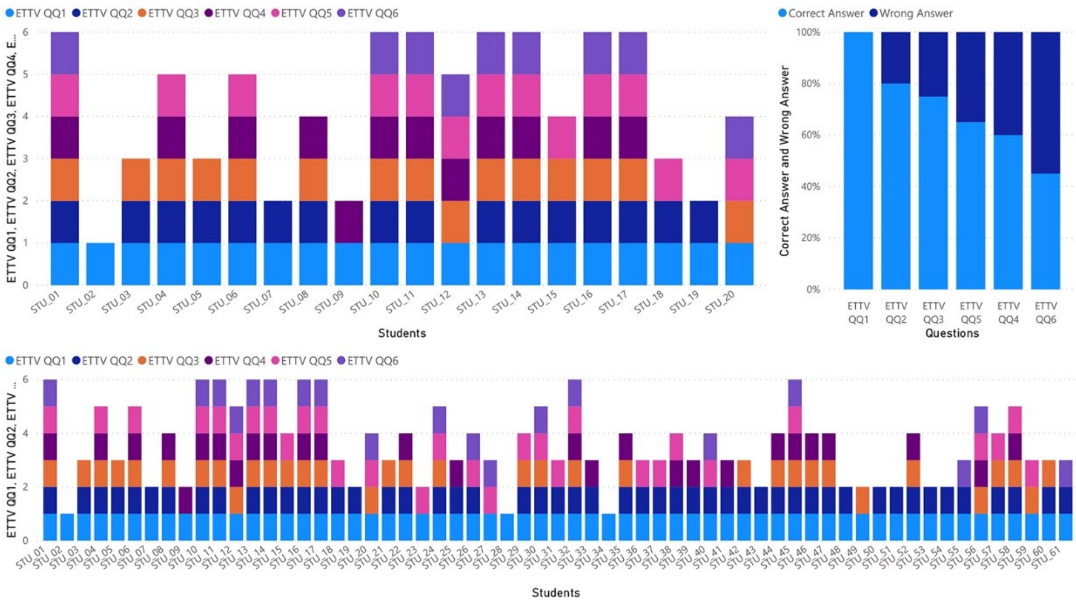

Figure 5. Stacked column charts of individual students and which questions they answered correctly for the ETTV Quiz.

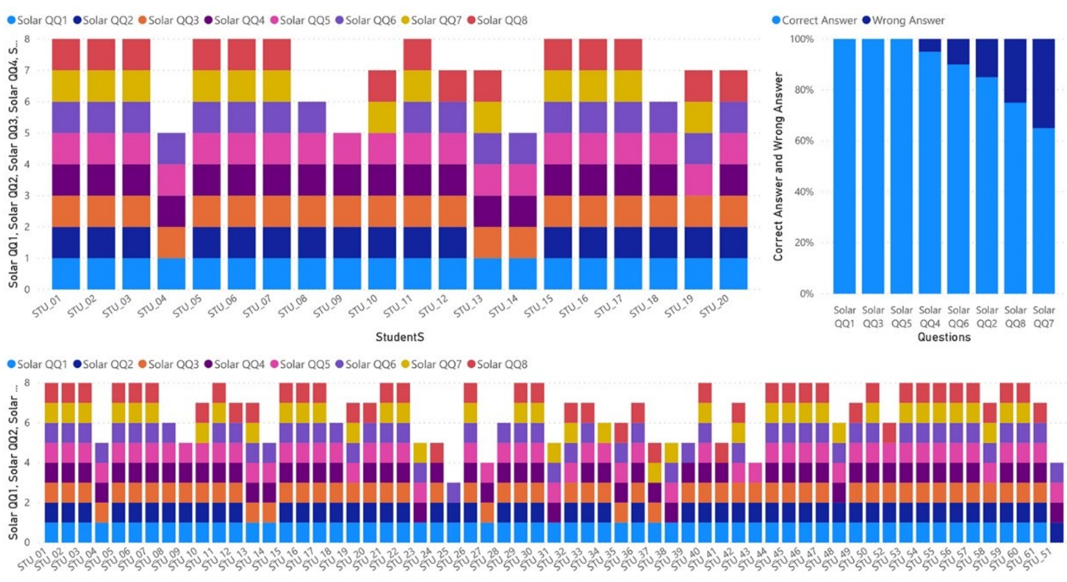

Figure 6. Stacked column charts of individual students and which questions they answered correctly for the Solar Technology Quiz.

Coupling these observations for the ETTV Quiz and Survey with the Solar Technology Quiz and Survey in Figure 7 and 8, reveals that the student STU_03 may find the ETTV calculations confusing and challenging. This is because for lesson on Solar Technology, which did not involve any calculation but is more related to basic scientific knowledge of Solar Technology, student STU_03 had full marks for the Solar Technology Quiz and he has also responded positively to the Solar Technology Survey. The survey questions are listed below:

1. After reading the learning material I had a good overview and understanding of the topic on solar technology for buildings.

2. Having a more focused explanation and discussion on key topics during lecture (flipped classroom) is better than a conventional lecture where the tutor only teaches through the presentation slides.
3. After finishing class, my understanding of the topic on solar technology for buildings has improved.

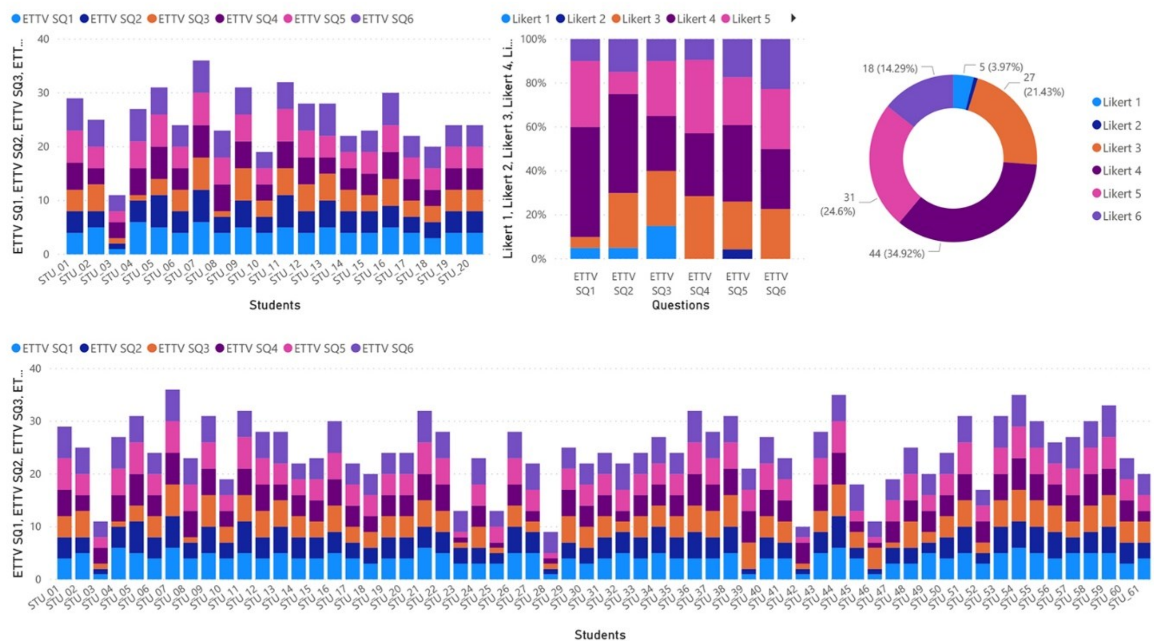

Figure 7. Stacked column charts and donut chart of students responses to ETTV survey questions.

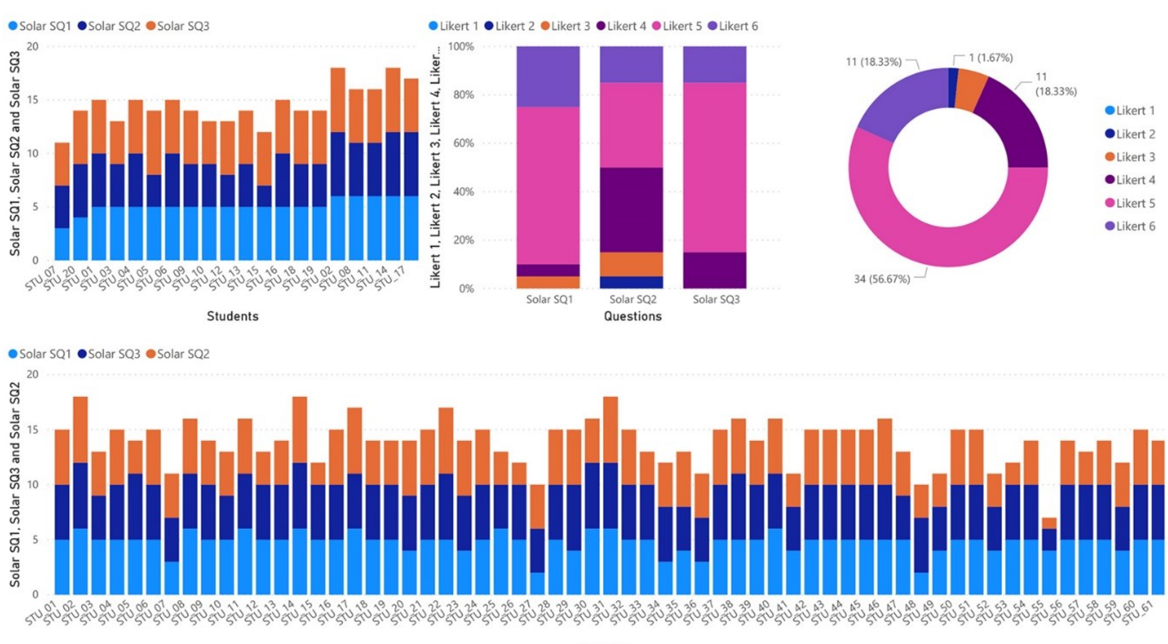

Figure 8. Stacked column charts and donut chart of students' responses to Solar Technology Survey questions.

CONCLUSION

The FLARET Framework aligns with the CDIO Standard 11 which recommends the use of a variety of learning assessment methods to measure the extent to which each student achieves specified learning outcomes. The action research was setup to evaluate the benefits and challenges of using the FLARET Framework to measure if students are achieving specific learning outcomes in flipped learning lessons. The assessment methods used are: a) the Grit Scale, b) in-class quiz and c) in-class survey. First, the FLARET Framework has three assessment methods which allows tutors to monitor students' progress in flipped learning and reveals the students self-directed learning readiness in relation to the gaps in the students' learning. The PCP provide a quick overview of the results from the three assessment methods. The comparison between the scores from the in-class quizzes and in-class surveys helped us to quickly pick up and correlate the discrepancies in students' understanding. This helps us intervene early to assist the students in their learning before their summative assessment at the end of semester. Second, the use Power BI provides us with the ability to push data to the visualization software instantaneously. However, the format of the dataset collected and the charts in Power BI have been properly synced. The big library of visualization charts to organize and visualize data in different ways to surface patterns and trends provides user with different ways to analyses the dataset. However, the process of data cleaning impede the process of analyzing the data quickly. This could be alleviate by properly setting up the quiz and survey forms such that the dataset collected are in its correct rows and columns to correlate direct to the charts setup in Power BI. This will reduce the amount of data cleaning required. Third, the analysis of the dataset collected postulates that the Grit-Perseverance score is a better indicator that students with higher scores are more likely to pass because they are more driven to perform well in their coursework. However, more studies need to be done to determine if there is a good correlation between students' performance and their Grit scores. For future work, we would need to expand the deployment of the FLARET Framework for more lesson topics to provide a wider and holistic evaluation of the entire module. In addition, other learning assessment methods could be added to complement the existing list of learning assessment methods in order to make the FLARET Framework robust.

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BIOGRAPHICAL INFORMATION

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DEVELOPING CURRICULA BY BLACK BOX METHOD

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ABSTRACT

A curriculum can by time develop to a collection of good courses created, executed, and further developed by individual teachers alone. This can lead to curricula where the connection between the courses cannot clearly be seen and the required inputs and outputs between the courses remain unclear. Courses with same content can be arranged twice or lead to a curriculum where crucial content is missing. In this paper we present two cases of curricula development utilizing the black box method. The first case is a curriculum of a recently started education. The curriculum is examined the first time after its creation by the faculty staff. Second case is a curriculum of an education that has been ongoing for several years. In the black box development method, the faculty staff discuss the courses in terms of input and output knowledge and skills only. Every course is considered as a black box. For each course, the faculty members involved in course implementation identify the specific knowledge the students should enter the course with and what knowledge and skills they should bring with them to future courses. The knowledge and skills are expressed as learning outcomes. By collecting this information from all courses in the curriculum, it is possible to identify the connections between different courses and address any inconsistencies such as unnecessary gaps etc. The black box exercise has been performed for two curricula. In the first stage the teachers identified the required input and expected output of the modules. The results from this stage show the need for increased collaboration between teacher teams as well as within the teams. The process has enhanced dialogue and productive discussions among faculty members and increased awareness of the whole curriculum.

KEYWORDS

Black box, curriculum development, higher education, chemical engineering, Standards: 2,11,12

DEVELOPMENT OF CURRICULA AND HOW WE ENDED USING BLACK BOX METHOD

The curriculum of the Degree Program in Chemical Engineering was redesigned in 2015 to comply with the new curriculum requirements and instructions of Turku University of Applied Sciences (Turku UAS). The main requirements at that time were to create a modular curriculum with entities of minimum 5 ETCS and thus avoid highly fragmented curriculum by integrating these entities to larger modules of 15 ECTS. In addition, the strategy of Turku UAS guided the use of innovation pedagogy (Lehto et al., 2013). Since that, the department of Chemical Engineering has expanded and includes today three Degree Programs: Chemical Engineering, Chemical Engineering (multiform) and Energy and Environmental Engineering**.** At the department of Chemical Engineering innovation pedagogy is implemented and applied through the CDIO concept in all curricula for all three Degree Programs.

According to the CDIO framework the curricula are reviewed by the faculty, students, and the advisory board. Department of Chemical Engineering has an advisory board consisting of stakeholders from regional and national companies. A review is made every second year by stakeholders. Their opinion is important, as the content in the curricula gives the elements, and knowledge, that the graduates take with them to their future employers.

In 2020 the Degree Programs were reviewed again, five years after the redesign 2015. It was time to make amendments to the curricula based on both feedback and experience. In general, it was considered that the transition to modular curricula was a success. The goal to create larger entities and to collect subjects connected to a topic to modules was achieved. Though, some problems were noted: Internal planning and discussions within the faculty were lacking and leading to problems. Feedback from student reviews indicated that same of the topics were introduced several times as they were included in multiple courses. It was also noted that the lack of internal planning and discussions led to the fact that some important parts fell entirely out of the curricula. This issue was discussed within the staff and led to the decision to monitor the curricula as whole. As a tool for the monitoring the black box method (Crawley 2007) was used.

THE CURRICULUM AND ITS CONTEXT

The curriculum of the Degree Program in Chemical Engineering is based on the long history of process technology education in Turku University of Applied Sciences (Turku UAS), collaboration and reflection with the local industry and universities, innovation pedagogy "Innopeda®", CDIO standards, strategy of Turku UAS and feedback from students and advisory board. The basic structure of curriculum in Turku UAS is simple and flexible even for rapid changes. There are only two categories in the curriculum: core competence and complementary competence. The curriculum structure is shown in Figure 1. All courses are in these two categories. The goal is to create flexible curriculum for the faculty and students without tight restrictions.

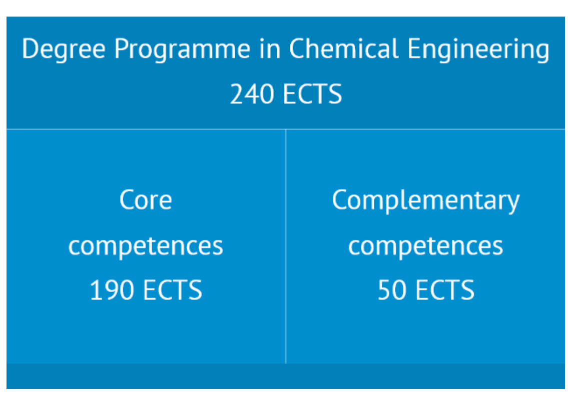

Figure 1. The structure of the curriculum in Chemical Engineering Program.

The goal of innovation pedagogy is to prepare the students to learn new skills needed for future engineering work. The role of teacher in Innopeda® is more like a coach rather than a traditional teacher. There are many similar elements in Innovation Pedagogy and the CDIO concept. The innovation pedagogy structure and competences are presented in Figure 2. Higher education strives to educate students for jobs that do not yet exists, using technologies that have not yet been invented.

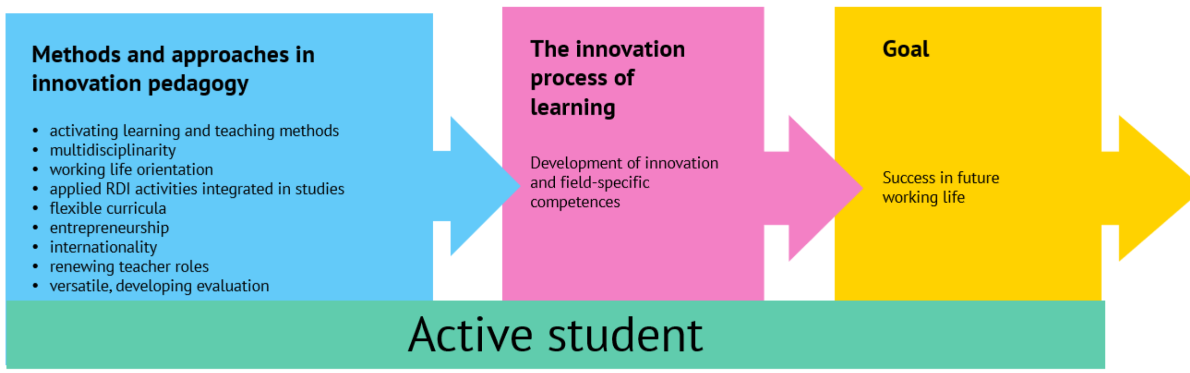

Figure 2. Innovation pedagogy and competences in Turku UAS.

Innovation and project management skills are recognized as one of the most important parts in Turku UAS curricula. Knowledge and skill requirements increase year after year. At the beginning of the studies there are mainly Turku UAS internal projects and the goal is to learn the basics in project management methods and project reporting. Third year Innovation project, Capstone, is often an external project performed in collaboration with the industry partner. These projects are more demanding compared to previous year projects. Innovation competence steps in engineering studies in Turku UAS are presented in Figure 3.

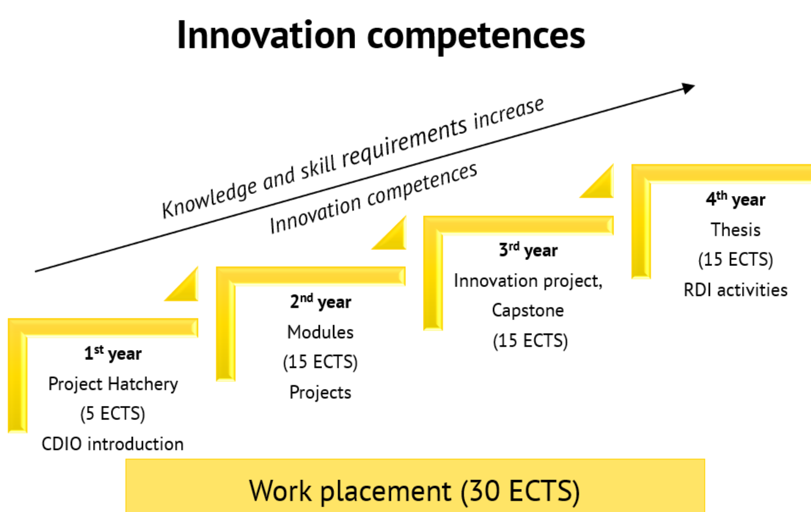

Figure 3. Innovation competences in Turku UAS.

CURRICULUM DEVELOPMENT METHODS

Although a lot is written about curricula it is difficult to find a single definition of what a curriculum is (Grant, 2014). IGI Global dictionary lists, on a search “what is curriculum”, 75 sources with definitions from a list of courses to a document that includes content, teaching strategies, assessment methods and learning outcomes (IGI Global). A brief literature review shows that different methods are used for curriculum development depending on the goal of the development work as well as the context.

In cases where the development work is steered by the goal to achieve a formal accreditation the work is usually mission bases, the programme must fulfil strictly defined external requirements. This is typical for healthcare and medical programmes, but formal accreditation can also be made for engineering programmes, see Wellington (2004). In fields, like chemical engineering, where the external steering is on recommendation level, e.g., the Bologna recommendations 2020, given by the European Federation of Chemical Engineering (EFCE, 2020), the freedom to design the curriculum is greater. Thus, is also the choice of development method greater. Within the engineering field the methods are often graphical and adapted from different system engineering methods. There are e.g., outcome-oriented methods as the black box method (Crawley, 2007), process-oriented methods; Y-charts (Rashid, 2014) or user-oriented with basis in object-oriented thinking (Somerville, 2006). In all cases there are also an attempt to incorporate methods and values in the curriculum.

The CDIO approach to curriculum development is based on the CDIO standards and the syllabus. The interest for more thorough examination of the curriculum was initiated by the teachers. The teachers were eager to know if the curriculum was a continuous path of courses, where the amount of knowledge is continuously increasing without leaving incoherencies in the learning paths. If incoherencies would be found in this study and the corrections needed would require changes in the whole curriculum, should the issues be addressed to the Dean of the Faculty for acceptance. Minor changes can be approved by the Head of School.

The black box method is used to visualize the links between courses modules in a curriculum. In this method all courses are represented by a black box. Only the input knowledge required for the course, and the output learning outcomes, are made visible. All faculty members are asked to produce a black box element of the course that are responsible for. These elements are then linked together via their input requirements and outcomes. (Crawley, 2007). The curricula for the programmes at the Chemical Engineering department could be developed using any of the mentioned methods. However, as Turku UAS has been a member of the CDIO initiative for several years it was most suitable to continue the development work with a CDIO approach using the black box method.

CASE STUDIES

The curriculum of two Chemical Engineering Degree Programmes have been developed by using the black box method. The examples are presented as case 1 and case 2.

Case 1: Recently started education

The teachers are experienced, but the multiform implementation created a need to increase teaching and counseling online. Teacher team consist of teachers working in several educations e.g., chemical engineering and ICT. To provide students with a combination of substance mastery and generic skills co-operation and sharing the practices are needed. The black box method (Crawley, 2007) is used as a tool to enhance the co-operation and to understand the big picture. The CDIO Syllabus 2.0 (Crawley, 2011) is utilized in identifying the intended learning outcomes.

As the courses are implemented for the first-time teachers formulate the course inputs and outputs while they are planning the implementation. A shared excel-file is used as a planning tool at this stage. The teachers fill in the excel-file independently and the contents are discussed during teacher team meetings. In the next stage a visual description is formed to make the connections between courses visible. In the Figure 4 an example of the visualization is presented. Only few inputs and outputs are selected in this example, there are significantly more inputs and outputs in the actual description. The description is utilized to identify gaps and redundances. It also helps to identify the interfaces and teachers that ensure the connections between the courses.

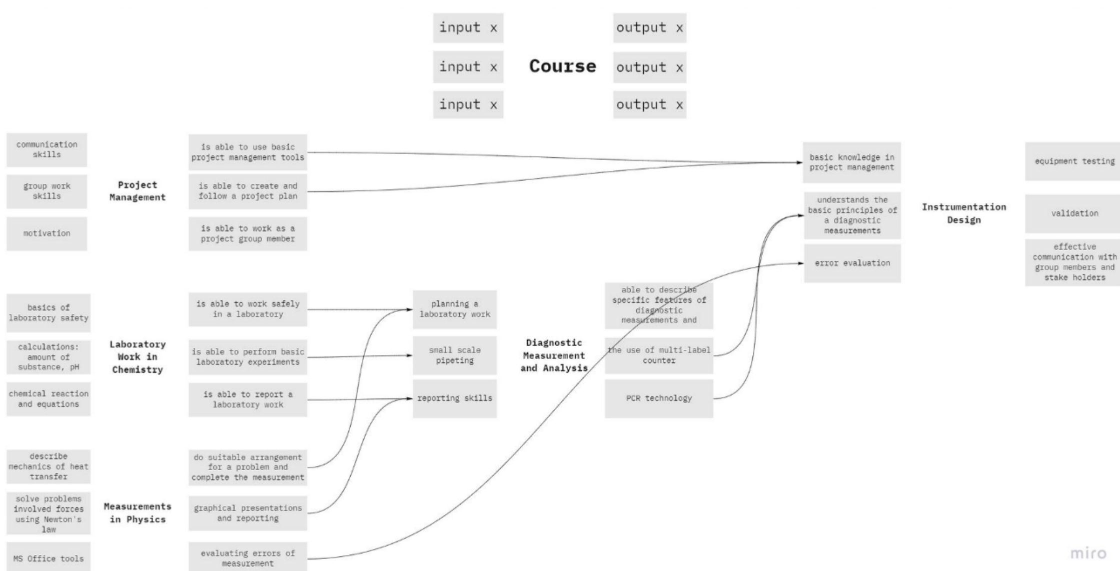

Figure 4. An example of the connections between courses.

Since the black box is used for design of a new degree programme from the very beginning, there is a possibility to react quickly if gaps or redundances are identified. When a teacher is planning the first implementation of the course, the outputs and the student feedback of the prior courses are available. By utilizing this method, it is easy to discuss the next implementation of prior courses if changes are needed.

CDIO Syllabus 2.0 (Crawley, 2011) is presented as a table in an excel-file (Figure 5). All courses in the curriculum are presented in rows and the CDIO Syllabus content in columns. At the first stage, teachers mark the skills and attributes covered in their course. The aim is to support the teachers in identifying and enhancing the cross-curricular competencies. A shared file acts as a tool to visualize the entity for the staff involved.

	1 Discliplinary knowledge and reasoning			2 Personal and professional skills and attributes					
	1.1 Knowledge of underlying mathematics and sciences	1.2 Core engineering fundamental knowledge	1.3 Advanced engineering fundamental knowledge, methods and tools	2.1 Analytical reasoning and problem solving	2.1.1 Problem identification and formulation	2.1.2 Modeling	2.1.3 Estimation and qualitative analysis	2.1.4 Analysis with uncertainty	2.1.5 Solution and recommendation
Cource									
Software Tools for Professionals 1		x	x						
Software Tools for Professionals 2	x			x		x	x		x
Project Management					x				x
Mathematics for Engineers	x	x	x	x	x	x	x		x
Differential calculus	x	x	x	x	x	x	x	x	x
Statistical Data Analysis and Experiment Design	x	x	x	x	x	x	x	x	x

Figure 5. An example of the use of CDIO Syllabus 2.0 table.

Now the second academic year is ongoing. All the courses implemented so far are documented in the black box file and in the CDIO Syllabus file. A new group has started their first academic year following the curriculum modified based on black box design. The use of black box methods has so far increased the communication and discussion between teachers even though the visual description of the entity is still lacking.

According to our experience so far, it is very important to document the process, steps, and the actions, while creating the final documentation of the black box exercise. This documentation is then utilized in creating a process flow chart that can be used as a tool in future development work. Formulating the inputs and outputs for a single course is not time-consuming and the work is done parallel by individual teachers and proceeds fluently. Generating the visual description takes more time and has turned out to be challenging. Few software has been tested but we have not yet been able to find a suitable and practical tool.

Case 2: Education that has been ongoing for several years

Bachelor's Degree Programme in process and food industry technologies were founded 1970. Today parts of old curricula can still be found in Chemical Engineering Programme curricula. The program name has been updated to correspond to new trends and the content of the program. But still the roots of basics process industry exist strongly in chemical engineering background in Turku UAS.

It is challenging to update the structures and content of a traditional curriculum. The black box –method offered a new and neutral tool to analyze the situation in a new way. The development work was performed as described in the previous chapter and the entire process is presented in Figure 6.

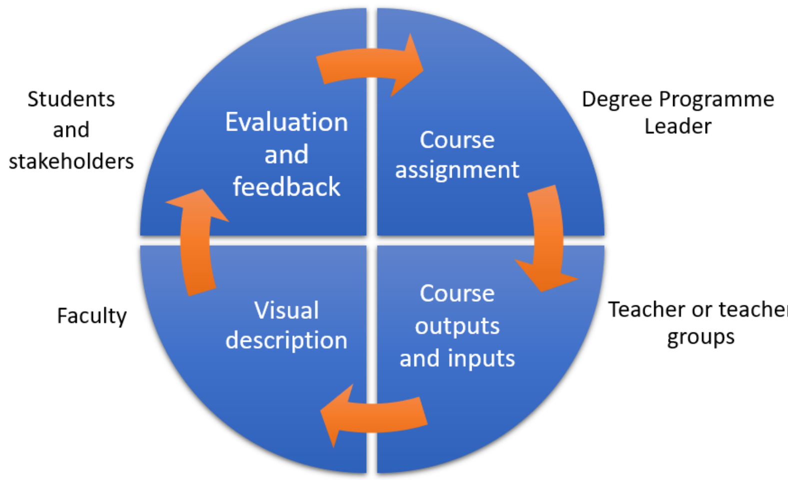

Figure 6. Black box development process.

CONCLUSIONS AND FUTURE DEVELOPMENT WORK

In the case of recently started education inputs and outputs are formulated by a teacher or the teachers that teach the course concerned. Biggers teams, consisting of teachers teaching courses in the same field, have been working with the inputs and outputs from the work described in case 2. The discussion is more profound from the beginning of the process when bigger teams are working together. On the other hand, in the case of the recently started education, it was easy to write the outputs and inputs for black box documentation while planning the implementation of a course. Furthermore, there was no need to arrange separate, time-consuming meetings, as it was in the case of the case example 2.

When the entire curriculum is reviewed as a whole, the big picture becomes visible sooner. Considerable amount of time must be reserved to complete the work. By reviewing the curriculum course by course, is less time required. On the other hand, longer time is needed to visualize the entity.

One of the most important result is that all the faculty members work together in this curricula development work. Active communication between managers, lecturers, researchers, and technical staff increases the general knowhow of courses and the connections between implementations. Changes in the curriculum can now be made rapidly and more efficiently.
As described earlier stake holders review the curricula every second year. In the sector of Chemical Engineering the advisory board is very active, and the co-operation is continuously developed. The black box documentation will be presented to the advisory board for them to give feedback as working life representatives.

Students should be engaged more during the whole development process. Students review the curriculum regularly but the black box and CDIO Syllabus documentation should be reviewed by the students as well.

An interesting continuation of this work could be a comparative study of the impact of the curriculum design method. Would a change of design method from black box to a process- or user-based method, in the same context, result in a different curriculum? A study like this could be an eye-opener for further development work.

The black box method activates staff members first in small groups with specified topics and at the end of the process the entire curriculum will be in focus. Better results will be achieved when the educational development work is done co-operatively. The development work continues in both programmes and will be repeated in two-years cycle.

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BIOGRAPHICAL INFORMATION

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IMPROVING STUDENTS ENGAGEMENT WITH ACTIVE LEARNING IN ENGINEERING OPTIMISATION LECTURES

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ABSTRACT

In optimisation, as for learning, the synthesises of previous knowledge and current information is essential to achieve defined objectives. The students' objectives are to fulfil the course's intended learning outcomes and possibly, at the same time, develop their knowledge, skills, and attitudes within the subject. The purpose of this work is to incorporate a more collaborative learning environment with active learning activities in the classroom to improve student learning opportunities, their perception of the course and their interest in the subject of optimisation. Within the CDIO initiative, active learning or experiential learning is stated as a key factor in engaging students directly in thinking and problem-solving activities. This can apply to different teaching activities such as assignments, lectures, and assessments. With active learning, the purpose is to involve students more actively in the learning process instead of relying on passive information transfer. Active learning methods aim to facilitate the students' process of creating their understanding of the topic by reflecting, questioning, conjecturing, evaluating and make connections between ideas whilst drawing on ideas, experiences and knowledge of others. In this work, diverse activities for incorporating more interactive learning in the classroom have been implemented in different course lectures, activities such as think-pair-share, mind maps, multiple-choice questions, incomplete hands and more. An evaluation of the students' perception of the course and the various activities was carried out at the end of the course. The most considerable improvement was with the overall impression of teaching. That improved between the years from 3.10 to 3.57. The most appreciated activity was the think-pair-share approach, which gave the students a cognitive break from the lecture slides to discuss the topic. However, the response rate was limited but did indicate the students' perspective and what was appreciated. The results will provide a good base for future development.

KEYWORDS

Optimisation, Engineering lectures, Active learning, Standards: 2,8,10

INTRODUCTION

In optimisation, as for learning, the synthesises of previous knowledge is necessary. The objective might be different for different disciplines, and for the students, their main objective will be different. For some students, the aim might be to get a passing grade, while others aim for the highest grade or something even more long-term. How well they will obtain their objectives depends on their available resources and their capability of putting new information in context. In optimisation, there is even a Teaching-Learning based algorithm (Rao *et al*., 2011). In the Teaching-Learning based optimisation, the process is divided into two phases: a teacher phase and a learner phase. The teacher phase entitles learning from the teacher, while in the learner phase, the learners interact with each other. In the traditional classroom, the second phase is, however, often left unsupervised.

The reference course in this work is the Engineering Design & Optimization course (PPU191) at the Department of Industrial and Materials Science at the Chalmers University of Technology, held during the first study period (LP1) in the autumn with approximately 40 students each year. This is an elective master-level course at the Chalmers University of Technology and is mainly attended by students from Product Development, Applied Mechanics and Automotive. The course has been developed during the past seven years by several people and follows the principle of the CDIO initiative. A detailed description of the overall experiences from the development, teaching and evaluation of the course has been summarised by Quist *et al*. (2017), focusing on the learning objectives and the project assignments. Video-based learning material has also been developed for the course by Bhadani *et al.* (2017). The course does have a good balance between optimisation's theoretical and practical aspects with a strong industrial connection. The theory is based on the principle of optimal design by Papalambros and Wilde (2017) and is supported by guest lectures and hands-on assignments.

Most pedagogical approaches are focused on the learner perspective, while in practice, lectures are most likely teacher-centred (Felder and Brent, 2016), which is often the case for the reference course. The problem was that students were often passively listening and only a handful of students asked questions during the lectures. As a teacher, it was difficult to confirm that the student understood the lecture's topic under these conditions. Active learning has been implemented previously in the course but in the form of assignments and workshops, not actively in the lectures. Wieman (2007) stated that people learn by creating their own understanding, and with learner-centred approaches, such as with interactive lectures, the aim is to facilitate the learning process. Within the CDIO framework, active learning is one of the 12 standards (Malmqvist *et al*., 2019). Active learning is considered to be an experiential learning method and aims to facilitate the students' process of creating their own understanding of the topic. Therefore, the purpose of this work is to incorporate a more collaborative learning environment with active learning activities in the classroom to improve student learning opportunities, their perception of the course and their interest in the subject of optimisation. At the same time, the main aim is to increase student engagement and interaction in class to improve their grade, the course evaluation and the number of master theses on the topic.

METHODOLOGY

An action research methodology was applied to investigate the application of active learning activities in Engineering Design and Optimisation lectures. Action research is described as a combination of theory and practice; and is an iterative process (Avison *et al*., 1999). For pedagogical action research, the focus is on a reflective part of the underlying pedagogical issue and methodology determining a series of actions to handle the issue. The purpose is to systematically evaluate the teaching to modify current practice (Norton, 2019).

In the following section, the methods related to active learning and the associated topics is described. After that, the implementation of the active learning activities is described. Finally, the evaluation of the implementation and their results are shown. The evaluation consisting of a closed-ended questionnaire was used to evaluate student's perspective on the active learning activities. The survey was conducted at the end of the course for practical purpose and with the expectation that students could provide a holistic perspective of their experience with different active learning activities. The collected data was analysed to produce indicative trends about students' perspective on their experience with different activities in the lectures.

METHODS

To effectively find appropriate methods, multiple teaching strategies need to be applied. There are several different methods available to support student interactions. However, in order to fully engage students, more aspects need to be considered than just including interactive learning activities. The approach here can be divided into three perspectives: create the right environment for the student interaction, incorporate interactive learning activities in the classroom, and set up systematic feedback for both the students and the teacher.

Learning environment

For an appropriate learning environment, different psychosocial aspects need to be supported to engage the students actively. Zapke and Leach (2010) have formulated different perspectives and actions to improve student engagement. The students need to:

- be able to enjoy the learning process,
- feel confident enough to share and contribute,
- feel support and engagement from the teachers,
- feel challenged but not overloaded,
- see the purpose of the subject and link it to prior knowledge
- interact with others that have different background

All these aspects aim to increase student self-belief and intrinsic motivation to construct their own knowledge (Zapke & Leach, 2010). Creating an appropriate learning environment takes time, and some researchers even state that it takes half a semester before the students feel comfortable participating in interactive activities (Cooper & Robinson, 2000). Hockings *et al.* (2008) noted that the student who reflect, question, conjecture, evaluate and make a connection between ideas whilst drawing on ideas, experience and knowledge of others are more deeply engaged. Smith (2000) proposed an informal cooperative learning strategy where the lectures were divided into segments of 10-12 min lectures followed by 3-4 min interaction activities. With the aim of creating a more cohesive and deeper conversation between the students to improve learning. However, there is a risk that it becomes a too predictable routine from some students' perspective (Felder and Brent, 2016).

Interactive activities

The means of creating more student engagement is with interactive learning activities. The interactions allow the students to reflect and re-formulate the information together with another learner. In Cooper and Robinson (2000), multiple small group approaches are described. This includes incorporating learning activities such as:

- Think-pair-share
- Think-pair-square

- Use incomplete hand-outs and slides
- Pose multiple-choice questions
- Quick-thinks – correct errors / compare
- Mind maps

Additional strategies are available for increasing engagement and interaction outside of the lectures (Rodríguez *et al*., 2019). These may include:

- Flipped classrooms
- Gamification material
- Simulators

Flipped classroom and gamification material has previously been implemented and documented for specific workshops and assignments in the course (Quist *et al*., 2017; Bhadani *et al*., 2017)

Feedback

Students satisfaction has been found to have a significant correlation with how quickly they got feedback (Felder & Brent, 2016 and from the teacher's acknowledgement of their expectations (Zepke & Leach, 2010). Feedback to the student can be defined as either directive or facilitative, where directive feedback refers to direct instruction of what needs to be revised, while facilitative aims to guide the student in their own revision (Black & William, 1998). In this course directive, formative feedback has been used. Detailed guidelines on formative feedback to enhance learning have been formulated by Shute (2008) and include aspects such as Focus feedback on the task, Be specific and clear, Keep feedback as simple as possible, Provide feedback after learners have attempted a solution and more.

Communication is vital for both students and teachers. The class is a diverse set of individuals with different experience and cultural background. It is therefore essential at the start of the course to state follow topics to minimise the risk of unconscious bias or any inherent assumptions:

- Clarify the lecturer and TA purposes and roles
- Highlight the code of conduct in the course
- Enquire about their educational background
- Provide a variety of support services

The feedback from different interactive learning activities provides the student with either a confirmation or correction to their answer. It also provides feedback to the teacher on the efficiency of the process of learning. The format of the feedback depends heavy on the format of the activity. This may include:

- Face-to-face communication
- Written summary, highlighting strengths and weaknesses
- Quizzes from Canvas
- Online personal response system for polls, such as Mentimeter
- Minute papers

IMPLEMENTATION

In the course Engineering Design & Optimization, 9 core lectures are focused on general aspects of optimisation. Those lectures, out of 16 in total, are the focus of this study. In the initial lecture, where the purpose is to introduce the general concept of optimisation, it is important to set the benchmark for the rest of the course. For the first part, the examiner and all TAs are present to go through the way of communication in the course by clearly stating the lecturers and TA roles during the course, the code of conduct and going through the variety of support service and channels for efficient communication between teachers and learner. That is to establish appropriate communication channels and clearly state the expectation of the students work.

During each lecture, two or more interactive activities were performed, and minute papers were available after each lecture. The number of lecture slides was reduced to allow for additional time for interaction and activities during lectures. Essential information was provided on the slides for students not able to attend the lecture. The methods and examples of how they were applied are described here in more details:

Think-pair-share

Think-pair-share was be incorporated in most lectures. The think-pair-share activity's objective is to help the students with the conceptual understanding of the topic or question, encourage student-to-student interaction, and support the students in sharing their ideas with their peers. This was done in combination with other methods such as concepts maps, open questions or compare.

Example: Asking direct questions relating to the reading material such as the definition of monotonicity or contextual question such as for boundary optima in what cases can it be useful to incorporate penalty or barrier functions.

Mind maps

The purpose of the concepts maps is to improve the students' conceptual understanding of optimisation, system structures and identify a logical relationship between different systems and subsystems. Each mind map is followed up with discussions and sharing the results with the rest of the class. This can also provide feedback to the lecturer, such as providing input on more appropriate case examples based on the student's background.

Example: Ask the student to map out their master program's knowledge base and identify the possible application of optimisation within that framework or create a concept map of a multi-objective or multi-system optimisation example and identify possible relationships and shared variables between different disciplines.

Open question

Posting an open question to be answered at the end of the lecture, with think-pair-share or other supporting methods, aims to promote more active participation during class and help the student reflect on the topic from a particular aspect. Collecting the answer from all students at the end of the lecture with tools such as Mentimeter also helps clarify the lecture's efficiency in providing the student with the correct information to answer the question satisfactorily.

Example: Core questions connected to the lecture's main topic, such as: what are the criteria for a well-bounded optimisation problem or what are the characteristics of gradient-free optimisation algorithms?

Multiple-choice questions

Multiple choice questions help highlight general misunderstanding of different topics, provide feedback to the lecturer on the students' understanding of the topic, and incorporate an iterative loop at the end of the lecture to highlight the lecture's essential aspects. It can be incorporated with compare or other similar methods. The questions can be posted during class or on the course webpage.

Example: Topic-specific questions such as identifying the active, inactive or semi-active constraint in an optimisation problem or selecting the correct definition of concepts such as the Lagrangian function.

Incomplete hand-outs

Incomplete hand-outs aim to promote more active participation during lectures and focus the students' attention on specific aspects of the topic to reduce their cognitive load. However, this can also activate discussions outside of the lecture room for those who cannot attend the lecture if incorporated into the PowerPoint lecture presentation.

Example: leave empty spaces in the presentation on a critical aspect of a definition. For example, suppose the Hessian is positive-definite. In that case, the variable is *blank space* or only provide the first step of calculating, such as determining the step length in a Gradient descent approach.

Minute paper

The purpose of the minute papers is to assess the students' perspective of what was difficult to understand during the lecture or their understanding of the material read before the lecture. This is also a channel for the students to express issues with the course, lecturer, or fellow students anonymously. The minute papers are available after each lecture for the students, often combined with a specific task or question.

EVALUATION

The implementation has been evaluated from two different perspectives. The first part includes the comparison between the course evaluation of 2018 and 2019. This is to get more information on the students' perception of the course in general, i.e., if the course has improved their opinion on the lecture structure and the teachers involved compared to last year's participants. The second part is the questions aimed at capturing the students' impressions on the implemented methods. This provides a quantitative comparison between the different approaches and qualitative information about their perception of an engineering course's active learning strategies. Hall *et al.* (2002) have demonstrated an approach to quantify the students' perception when evaluating multiple teaching strategies.

In the course evaluation, the students were asked to give their opinion on if the activation methods supported their learning process during the lecture on a scale between 1 - Disagree completely to 5 – Agree completely. The same applied to the different tools used during the study period as well. Finally, they were asked for suggestions on how this could be improved. Out of 36 students registered for the course, 14 completed the course evaluation, which counts for 39 % of the course participants. In the previous year, 20 answered the course evaluation survey, about 44% of the course participants.

RESULTS

One of the initial results was clear in the first couple of weeks into the course. The students were not using the minute papers. Instead, the students would come up during the break or after the lecture with specific questions for further explanations. The minute papers were therefore dropped after three weeks. The score results from the course evaluation (Figure 1) show that the students' appreciation for the course structure increased from 3.75 to 4.00, the teaching worked well, changing from 3.10 to 3.57 and the students' appreciation for the course literature increased as well from 3.10 to 3.57. While the overall impression of the course remained similar, changing from 3.70 to 3.71. In general, the student opinion on the course remains similar to the year before.

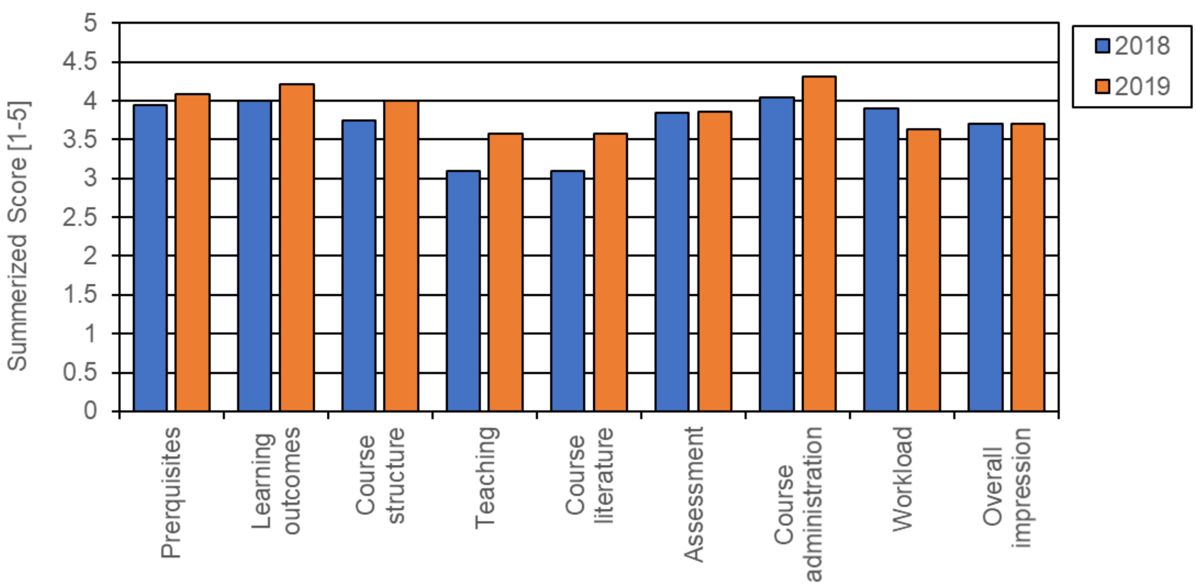

Figure 1. Overall course evaluation for 2018 and 2019.

However, the course evaluation is focused on the course as a whole, not a specific part of it. Areas that the active learning activities should affect did improve compared to the previous year. The most improvements were on the question: if the student perceived that the teaching went well. However, the activation activities were implemented in half of the lecture (eight) and two of the lectures were new compared to the previous year. Making it impossible to make any general assumption of the significance of the implemented methods. The questions specifically related to the implemented methods in the course survey were as follows:

Did the methods help your learning process of different topics during the lectures?

1. Did the Think-pair-share discussions help your learning process?
2. Did the Mind maps help your learning process?
3. Did the Word clouds help your learning process of different topics?
4. Did the True and false statements help your learning process?
5. Did the Multiple-choice questions help your learning process?
6. Did the Incomplete statements help your learning process?

7. Did the calculations in slides help your learning process?
8. Did the calculations on the board help your learning process?
9. Did stating a direct question help your learning process?

Figure 2 illustrates the average points of each question if the student agrees or disagrees with the statement that the method in question supported their learning process. The value five corresponds to "Agree completely" while one corresponds to "Disagree completely". The proportional distribution within each question is also illustrated with the different colours.

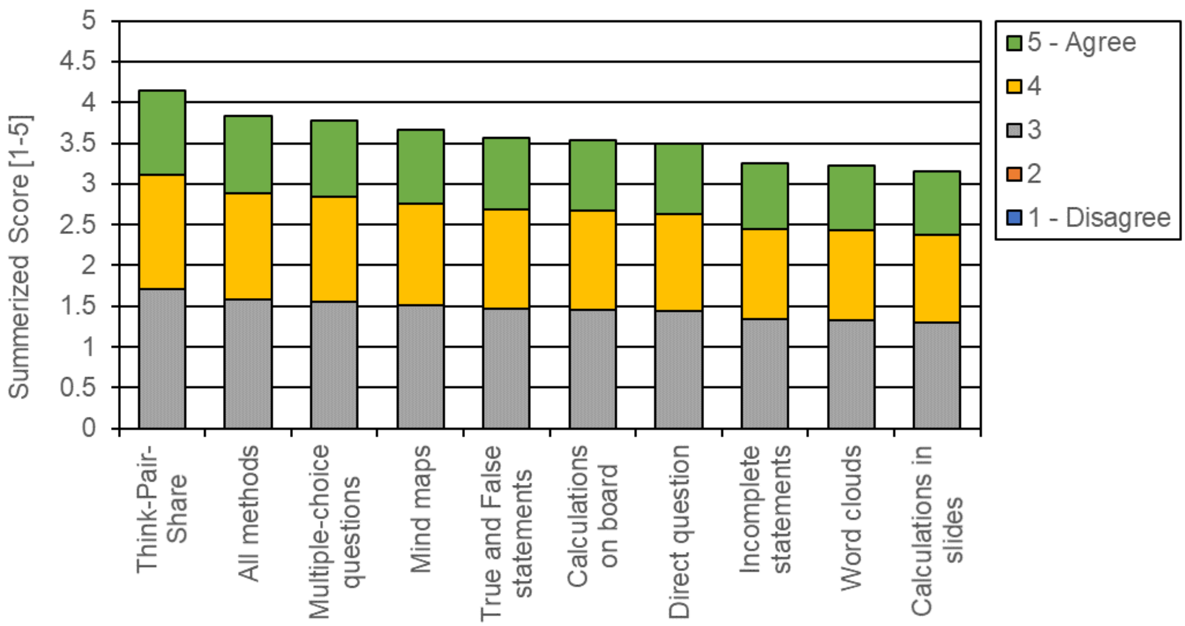

Figure 2. Evaluation of the activation strategies.

In general, the students appreciated the activation methods, and from the evaluation, the think-pair-share was the most appreciated activation method. The think-pair-share activity had an average score of 4.14. After that came the multiple-choice question, the mind maps and the true and false statements. At the lower end of the evaluation of the methods are the calculations on slides, word clouds and incomplete hand-outs. The students also appreciate more having examples calculated on the board instead of being provided in the slides, which would entail more activation during the lecture.

The questions specifically related to the supporting tools in the course survey were as follows:

1. Did support tools work well during lectures?
2. Did Socrative work well during lectures?
3. Did Mentimeter work well during lectures?
4. Did the hand-outs work well during lectures?

Figure 3 illustrates the average points of each question if the student agrees or disagrees with the statement that the tools in question worked well to facilitate their learning process. The value five corresponds to "Agree completely" while one corresponds to "Disagree completely". The proportional distribution of within each question is also illustrated with the different colours.

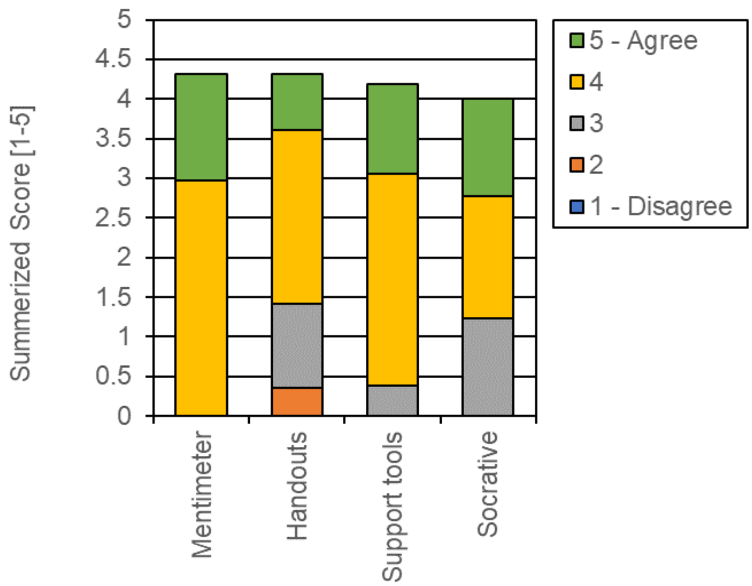

Figure 3. Evaluation of the supporting tools.

The support tools used during the course were all highly appreciated, with all scores above 4. No issues came up during the lectures, and the students had no difficulty with the corresponding app or webpage when answering questions.

The course's final grade is a balance between the format of the content included in the exam and students' preparation for the exam. Since the exam changes every year, it is difficult to use it to measure students' performance. In the previous year, the average student grade, who passed the exam, was 3.9 compared to the average of 3.5 this year. However, the number of students that did not pass the course went from 19 to 5 between the years. In the previous year, ten students didn't even attempt the final exam.

DISCUSSIONS

During the lectures, I experienced more interaction with the student. The think-pair-share activities created a good discussion environment that was difficult to stop sometimes. Stating a related question on the topic, with true or false statements, multiple-choice questions, incomplete statement, or other means. Gave all the students' possibility to discuss the question or statement, answer the question and then reflect on the results. After the answer was revealed, the second round of discussion usually started by connecting the question to a specific lecture slide. Stating a direct question was difficult and usually resulted in only a few students participating in the activation.

The process of creating and implementing active learning activities was simple. After the initial demos, the lectures' questions were configured on the related app or web page in minutes. In these implementations, both Socrative and Mentimeter were used. The results can be logged to keep track of the students' general development if the same approach is implemented throughout the course. The results from each task will help develop the questions and their format for the course next year. The time it took to conduct those activities requires some alteration of the lecture material in content full lectures. This entails putting an extra focus on the essential part of the theory and directing them to find additional information that is good to know. Creating an efficient pre-lecture preparation material will also help with time allocation.

The lectures' format will be further developed for next year, focusing on think-pair-share activities in each lecture. Activities such as multiple-choice questions and true and false statements will be done regularly to get feedback on the students understanding of the subject during a lecture or from the request reading material. Calculations are an essential part of the course material that needs to be revisited and changed to improve their impact on the learning process.

The implementation's main goal was to increase student engagement and interaction in class to improve their grade, the course evaluation, and the number of master thesis on the topic. During the study, general observations were that active learning does activate the student efficiently during lectures and makes them more engaged both during the lecture and between them. By introducing discussion and reflection during the lecture, the learning process should also improve. The average course grade became lower between the years. However, the percentage of students attempting the final exam and the student that did not pass reduced significantly. After the course, several students have also approached me with master theses proposals related to optimisation. Five optimisation related design projects were conducted during the following spring, providing additional examples for the course. Compared to one from the previous year.

CONCLUSIONS

The different active learning activities worked well from the authors' perspectives. The students appeared to be more engaged and interactive during lectures, more students passed the course examination and more applied optimisation in their thesis work. The study was explorative with several different methods tested to see what worked well in this particular situation with this topic and these students. Each year the course content and structure will change slightly based on the course evaluation. However, based on the experience from the implementations, the active learning activities will be an integrated part of the course in the coming years.

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INTENDED LEARNING OUTCOMES OF SEVEN FINNISH B.SC. IN IT PROGRAMS

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ABSTRACT

Defining the intended learning outcomes is a significant part of curriculum design. Especially, the program-level competence requirements outline the objectives of the education, align the more detailed program structures and content of the curriculum, and create the basis for constructive alignment. Several different bodies aim at defining the goals of engineering programs on different levels of abstraction. Some of these documents can be considered as statements of the 'minimum threshold'. Respectively, others provide detailed guidelines to support the design of post-secondary programs in specific engineering fields. For example, the CDIO Initiative has defined a general reference syllabus aiming at creating a taxonomy of engineering learning rationalized against the norms of contemporary engineering practice. While designing new engineering programs, it is interesting to study how different universities have documented the intended learning outcomes of their programs in related domains. In this paper, the program-level learning objectives of seven Finnish B.Sc. in Information Technology programs are discussed and reflected with the CDIO Syllabus based on the information available on the public curriculum descriptions.

KEYWORDS

Curriculum Design, Competence Requirements, Information Technology, Standards: 1, 2, 11

INTRODUCTION

Focusing on the outcomes of educational experiences in curriculum design emphasizes what a learner is expected to know, understand, and be able to demonstrate after a learning process. This student-centered approach is generally applied worldwide also in the context of engineering education. In Europe, the outcomes-based approach was facilitated by the so-called Bologna Process that aimed at creating common language and transparency for higher education. (Gonzáles & Wagenaar, 2008)

The definition of the intended learning outcomes is one of the most significant parts of the curriculum design process. Especially, the program-level objectives of the education align the more detailed program structures and content of the curriculum, and create the basis for assessment. These intended learning outcomes should guide all the decisions connected to the design, implementation, and evaluation of the degree program. Besides, the program-level outcomes are often included in the general description of the program that is frequently used when presenting the program to potential applicants, students, faculty members, and different stakeholders. The intended learning outcomes provide a basis for constructive alignment (Biggs, 1996); i.e. the interplay of the teaching/learning activities and the assessment. Constructive alignment provides a framework for reflecting the fundamental questions of teaching and learning: “1) What do I want my students to learn, 2) What is the best way in my circumstances and within available resources of getting them to learn it, and 3) How can I know when or how well they have learned it?” (Biggs & Tang, 2011)

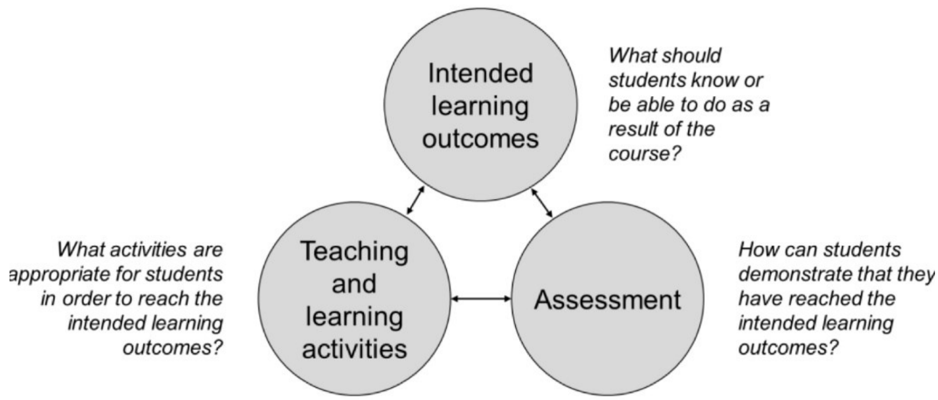

Figure 1. Constructive alignment as illustrated by Crawley et al. (2014).

Several different bodies aim at defining the overall goals of engineering programs on different levels. For example, European Network for Engineering Accreditation (ENAEE) has defined a set of outcomes that describe the knowledge, understanding, skills, and abilities that an accredited engineering degree program must enable a graduate to demonstrate (ENAEE, 2015). They are to be considered as the 'minimum threshold' to be fulfilled to assure the quality of engineering programs. These outcomes do not detail specific engineering domains but they approach the desired competencies via eight learning areas: Knowledge and understanding, Engineering Analysis, Engineering Design, Investigations, Engineering Practice, Making Judgements, Communication and Team-working, and Lifelong Learning. For example, Bachelor-level graduates should be able to demonstrate *knowledge and understanding*:

- “… of the mathematics and other basic sciences underlying their engineering specialisation, at a level necessary to achieve the other programme outcomes;
- … of engineering disciplines underlying their specialisation, at a level necessary to achieve the other programme outcomes, including some awareness at their forefront;
- as well as awareness of the wider multidisciplinary context of engineering.”

Also, the Criteria for Accrediting Engineering Programs by the Accreditation Board for Engineering and Technology (ABET) (2019) steer general curricular development globally. ABET requires that each engineering program shall have documented student outcomes that support the program’s educational objectives. The general learning outcomes have been outlined by seven learning areas that may be complemented by additional objectives articulated by the program itself. For instance, the graduate shall demonstrate “*an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics”* (ABET, 2019). In addition to the general learning outcomes, an engineering program must satisfy the specific Program Criteria that interpret the general criteria as applicable to a given discipline. According to ABET (2019), the curriculum of a Software (and similarly named) Engineering program:

> "…must provide both breadth and depth across the range of engineering and computer science topics implied by the title and objectives of the program. The curriculum must include computing fundamentals, software design and construction, requirements analysis, security, verification, and validation; software engineering processes and tools appropriate for the development of complex software systems; and discrete mathematics, probability, and statistics, with applications appropriate to software engineering."

Different disciplinary organizations provide detailed guidelines to support the design of post-secondary engineering programs. In the field of computing, the Computing Curricula of the Association for Computing Machinery (ACM) (2005) is a widely used reference model that provides detailed discipline-focused undergraduate curriculum guidelines for different subdomains of the field. The ACM documents cover undergraduate degree programs in Computer Engineering, Computer Science, Information Systems, Information Technology, and Software Engineering. The overview report provides a comprehensive overview of the field and a comparison of the expected competencies the major threads of computing programs. In short, the Software Engineers should "*be able to properly perform and manage activities at every stage of the life cycle of large-scale software systems"*. The ACM guidelines have been detailed in separate documents for each reference program. For example, the Curriculum Guidelines for Undergraduate Degree Programs in Software Engineering (ACM, 2014) describes what should constitute an undergraduate software engineering education. The learning objectives are approached via seven competence areas. That is, the graduates of an undergraduate program should be able to demonstrate *Professional Knowledge*, *Technical Knowledge*, *Teamwork*, *End-User Awareness*, *Designing Solutions in Context*, *Performing Trade-Offs*, and to show evidence on *Continuing Professional Development*.

The CDIO Initiative (www.cdio.org) has defined a general reference syllabus aiming at creating a taxonomy of engineering learning. The CDIO Standard #2 (Learning Outcomes) underlines the importance of the outcomes-based approach to ensure that students acquire the appropriate foundation for their future (CDIO, 2020). The objective of the CDIO Syllabus (Crawley et al., 2011) is to create a clear and generalizable set of goals for undergraduate engineering education to form the basis for educational and learning outcomes, the design of curricula, as well as the basis for a comprehensive system of student learning assessment. The guiding principle of the CDIO Syllabus is that engineers engineer; they build systems and products for the betterment of humanity. *"Graduating engineers should be able to conceive-design-implement-operate complex value-added engineering systems in a modern team-based environment"*. The CDIO Syllabus v2.0 is organized using four first-level competence items: *1) Disciplinary knowledge and reasoning, 2) Personal and professional skills and attributes, 3) Interpersonal skills: teamwork and communication,* and *4) Conceiving, designing, implementing, and operating systems in the enterprise, societal and environmental context*. These items are detailed further using second and third-level contents.

These guidelines aim at facilitating the design of high-quality engineering programs. They address similar themes but contain differences in their approach, level of details, and disciplinary focus. The learning outcomes linked together with purposeful learning activities and assessment are fundamental components of curriculum design. Yet, they are subject to criticism, too. For example, there is a risk that the outcome schemes become overly complex and detailed causing that they can be limiting rather than liberating guidelines (Tam, 2014).

RESEARCH QUESTION AND METHOD

Universities invest significant efforts when designing their programs and curricula to meet the mission and vision of each program leading to graduates able to demonstrate the intended learning outcomes. While planning and updating curricula, it is useful to study the different reference models and requirements available. In addition, it is an interesting question of how different universities have selected to describe their programs. This provides insight and advice on different approaches to address the task.

In this paper, the program-level learning objectives of seven Finnish B.Sc. in Information Technology (or a related domain) programs are studied based on the information available on public curriculum descriptions online. The contents of the intended learning outcome statements are reflected with the CDIO Syllabus. The intention is not to evaluate the programs or the curriculum artifacts but rather to provide an overview of how the learning outcomes have been documented in the program-level descriptions. The following seven different engineering degree programs leading to the degree of Bachelor of Science (Technology) provided by different Finnish universities were selected for this study:

- Aalto University (https://www.aalto.fi/en): Information Technology [Finnish: Automaatio- ja informaatioteknologia, Informaatioteknologia]
- LUT University (https://www.lut.fi/web/en/): Information Technology (Specialization in Software Engineering) [Finnish: Tietotekniikka, suuntautumisena ohjelmistotuotanto]
- Tampere University (https://www.tuni.fi/en): Computing and Electrical Engineering, Information Technology [Finnish: Tieto- ja sähkötekniikka, Tietotekniikka]
- University of Jyväskylä (https://www.jyu.fi/en/frontpage): Information and Software Engineering [Finnish: Tieto- ja ohjelmistotekniikka]
- University of Oulu (https://www.oulu.fi/university/): Computer Science and Engineering [Finnish: Tietotekniikka]
- University of Turku (https://www.utu.fi/en): Information and Communication Technology [Finnish: Tieto- ja viestintätekniikka]
- Åbo Akademi University (https://www.abo.fi/en/): Computer Engineering [Swedish: Datateknik; Finnish: Tietotekniikka]

Information on all these programs is available on the universities' websites. Most of the sites seem to be intended for potential applicants, yet the format and style of the sites vary significantly. Thus, this study focuses on the descriptions connected to the curricula published in study guides or similar online documents. A limitation of this approach is that there may be other documents detailing the intended learning outcomes that cannot be accessed using these references. However, studying the public curricula provides an interesting overview of the descriptions and corresponds to the visibility of university external bodies, e.g. potential applicants or collaborators who are interested in the programs.

The studied Bachelor's programs are not available in English and the respective curriculum descriptions are available only partly in English. That is, the quotations have been translated from Finnish or Swedish to English by the author and some of the nuances may have been lost in the process. Links to the original-language documents are provided but these links tend to change over time. The author has been involved in the preparation of the curriculum of the Degree Programme in Information and Software Engineering of the University of Jyväskylä. That may have caused a bias; yet the aim has been to study all the descriptions using a similar perspective.

RESULTS

The curricula of the studied programs have been structured in different ways. Some programs are larger entities that are divided to several major subject tracks whereas others are more focused and contain less optional paths. All except one of the curricula have a general description that discusses the program's contents and the intended learning outcomes. However, the format and style of the description vary significantly. Some descriptions have separate sections focusing on the intended learning outcomes and others discuss them in more general terms. All study guides contain links to more detailed course lists including separate descriptions of each course. The course-level descriptions follow rather similar structure detailing the learning outcomes, contents, and assessment principles of each course.

An overview of the program-level descriptions of the studied degree programs is included in Appendix 1. For each program, the general structure, central parts of the content, and style of the description are presented focusing on the discussion of the program-level intended learning outcomes. In addition, the length of the descriptions/sections is indicated as the number of words in the original language to illustrate the extent of each description. Short examples of the sections containing learning outcomes descriptions are presented for each case to provide an overview of the used style of discourse.

The intended learning outcomes and other mentioned learning areas and goals were mapped to the competence areas included in the CDIO Syllabus version 2.0 (Crawley et al., 2011). As the level of detail of the program descriptions varies, the comparison was limited to the second level competence items of the CDIO Syllabus. However, the third level competence items were used to guide the mapping, i.e. to determine whether a second level competence item was covered by the description or not. In addition, the topic of Sustainable Development was included in the analysis separately. This perspective was added to reflect the presence of the topic in the texts as its importance as a part of the learning objectives of the higher education programs is widely discussed currently.

The results of the mapping are presented in Table 1. The aim was to determine if most parts of a respective competence item have been covered in the description (marked with 'X' in Table 1), only some parts of the competence item have been discussed (marked with '(X)'), or if the item seems not to be present in the description (marked with '-'). As the format and length of the descriptions were rather different from each other, this task appeared to be difficult using this limited approach. In other words, the results shall be considered only as guiding reflections of the descriptions – not as a comprehensive comparison or an attempt to evaluate their quality.

All the descriptions cover both generic engineering competencies and subject-specific intended learning outcomes. Yet, it is difficult to make a difference between the core/fundamental and advanced engineering knowledge areas mentioned separately in the CDIO Syllabus. In addition, the scientific thinking connected mainly to the competence items 2.2-2.3 is not very clearly present in most of the descriptions. One probable reason for this is that these competencies are typically considered as core contents of the Master's programs and they may be intentionally left for a minor role in these Bachelor's programs. Furthermore, communication, collaboration, and teamwork skills were mentioned in all the descriptions.

Regardless of the differences between the descriptions, some findings can be made based on the mapping. For example, the description of Aalto University discusses engineering reasoning, problem-solving skills, and the competencies of analytical thinking very widely. LUT University seems to put weight on the business context of engineering, and University of Jyväskylä highlights the societal competencies and human-oriented connections of the field of Information Technology. Tampere University emphasizes the importance of Science and Mathematics, and the University of Oulu describes the multitude of product and system areas the graduates will be able to work with, as well as touches the operating/production domain of the engineering profession, too. The description of the University of Turku contains a clear focus on the diversity of nature and sustainable development, and even links these topics to the subject-specific competencies and opportunities.

Table 1. Mapping of the learning outcome definitions of the studied program descriptions and the CDIO Syllabus 2.0 second-level competence items.

	AALTO	LUT	TUNI	JYU	UO	UTU	ÅAU*
1 Disciplinary knowledge and reasoning							
1.1. Knowledge of underlying mathematics and sciences	X	(X)	X	(X)	-	X	-
1.2 Core engineering fundamental knowledge	X	X	X	X	X	X	(X)
1.3 Advanced engineering fundamental knowledge, methods and	(X)	(X)	(X)	(X)	(X)	(X)	-
2 Personal and professional skills and attributes							
2.1 Analytic reasoning and problem solving	X	X	X	X	X	X	X
2.2 Experimentation, investigation and knowledge discovery	X	-	(X)	(X)	(X)	(X)	-
2.3 System thinking	X	(X)	(X)	(X)	(X)	(X)	(X)
2.4 Attitudes, thought and learning	X	X	X	X	X	X	-
2.5 Ethics, equity and other responsibilities	(X)	(X)	(X)	X	(X)	X	-
3 Interpersonal skills: teamwork and communication							
3.1 Teamwork	X	X	X	X	X	X	-
3.2 Communications	X	X	X	X	X	(X)	X
3.3 Communications in foreign languages	X	X	X	X	X	(X)	-
4 Conceiving, designin, implementing and operating systems in the enterprise, societal and environmental context…							
4.1 External, societal and environmental context	(X)	(X)	-	X	-	X	(X)
4.2 Enterprise and business context	(X)	X	(X)	(X)	-	(X)	(X)
4.3 Conceiving, system engineering and management	X	(X)	(X)	X	(X)	(X)	(X)
4.4 Designing	X	X	(X)	(X)	(X)	(X)	-
4.5 Implementing	(X)	X	-	(X)	(X)	-	-
4.6 Operating	-	-	-	-	(X)	-	-
>>> Sustainability-connected competences/outcomes included	(X)	-	-	X	-	X	-

* No description or learning outcome definitios included in the Study Guide (curriculum), analysis based on program homepage only.
X = The competence item has been mostly covered in the description, (X) = Parts of competence item have been mentioned,
- = The competence item has not been included

CONCLUSIONS

Despite the limitations of this study, it was interesting to study the curricula and, especially, the different ways to describe the program-level intended learning outcomes. Even though all these programs represent the same engineering domain originating from the same country and institutions regulated on a similar basis, there are significant differences in the structure, extent, and style of the ways to describe the intended learning outcomes. The pedagogical policies, instructions, and traditions of the different universities and faculties affect the way these intended learning outcomes are defined, expressed, and documented. Yet, an interesting question is how well the descriptions de facto reflect the visions, profiles, and learning cultures of each program. Do they truly affect the contents and processes embedded into the program in such a way that it makes a difference in the competencies of the graduates?

All the studied descriptions aim at defining the subject-specific competencies as well as the other intended learning outcomes that connect to both the engineering profession and the generic competencies of a university-educated individual. These outcomes contain connections to the definitions and reference guidelines published by different international bodies, too. In this study, the CDIO Syllabus (Crawley et al., 2011) was utilized as a tool to reflect the descriptions.

The study guides are typically complemented with various sources of information such as program homepages, admission guides, social media feeds, etc. This study did not cover all the available documentation available for the respective degree programs but focused on the online study guides only. Yet, it seems obvious that it is not very easy to get a detailed overview of the programs if, for example, a person unfamiliar with the disciplinary notation is seeking information to determine which of the programs to select for future studies.

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APPENDIX 1 - OVERVIEW OF THE PROGRAM-LEVEL DESCRIPTIONS

Aalto University (AALTO): Information Technology

The Bachelor's degree program of the School of Electrical Engineering of the Aalto University has been organized so that the wide-range program has a general description covering the common structure and intended learning outcomes. This description is further specified separately for each of the four majors of the program. The general part of the curriculum guide (Aalto University, 2020a) contains a description of the structure of the Bachelor's program and a section entitled *Learning Objectives*. This section is followed by a notation explaining the course codes of the school. Besides, the curriculum guide contains links to the course list of the common basic studies, major study options, minor studies, thesis instructions, and guidelines on the planning of the studies. Each of the majors contains a short description of the option including the major-specific learning outcomes followed by a course list. The course lists contain a separate description of each course.

The general Bachelor-level learning outcomes (Aalto University, 2020a) are discussed describing the different knowledge and skills developed during the studies. These descriptions seem not to have been written using Bloom-style (Bloom et al., 1956) learning statements. The learning outcomes have been divided into four sections: 1) *Major and minor subject* (discussing general and subject-specific competencies developed), 2) *Engineering reasoning and working methods*, 3) *Study skills and foundation to Master-level studies*, and 4) *Working-life skills*. The description (427 words in Finnish) defines a wide range of learning objectives and contains guiding elements for students to plan their studies. The description of the Information Technology major (Aalto University, 2020b) (in total 142 words in Finnish) shortly introduces the field and adds details to the subject-specific intended learning outcomes. The style of the major-specific text seems to be a combination of generic discussion of the competencies and Bloom-style definition of the learning outcomes. Examples of the descriptions:

> General Bachelor program description; beginning of the Engineering Reasoning and Working Methods section: *"The B.Sc. (Tech.) graduate has gained competencies for the fundamentals of engineering-scientific thinking, reasoning, and working methods. During the studies, the student learns to understand the basic theories and concepts of his/her field, and to apply them in central research and development tasks connected to the field. The student constructs an overview of the professional practices of the field. The student can apply the methods of Science and Mathematics in the tasks of his/her field. … "*
>
> Major-specific description (Information Technology) example: "*The studies create a strong theoretical foundation in Mathematics and Science that is connected to the technological competences in Information Technology, Wireless Communication, and Data Networks. Application of theory to solving practical problems will be learned in experimental exercises."*

LUT University (LUT): Information Technology (Specialization in Software Engineering)

The study guide (curriculum) description (LUT University, 2020) consists of a bulleted list of the intended learning outcomes followed by basic information of the program (degree, extent, duration) and a course list. The course list contains a separate description of each course.

The list of the intended learning outcomes has been written as a numbered list that contains 11 learning statements ("*The graduate of the program is able to…*"). The statements have been written applying a taxonomy that seems to follow the principles originally presented by Bloom et al. (1956). The length of the description written in Finnish is 172 words. Two of the learning statements are directly focused on subject-specific competencies, two are mainly connected to teamwork and communication skills, two to project management skills, and two to business-oriented thinking. The other outcomes deal with systemic and holistic thinking, life-long learning, and ethical competencies. For instance, the first learning statement has been defined as follows:

> The graduate is able to *"…develop complex and scalable software applying the Software Engineering principles, tools and processes, as well as the theories and methods of Computer Science and Mathematics."*

Tampere University (TUNI): Computing and Electrical Engineering, Information Technology

The study guide (curriculum) description (University of Tampere, 2020) contains a general description that includes only one section entitled *Learning Outcomes*. In addition, the curriculum includes basic information of the program (degree, extent, campus, classifications, etc.) and a course list. The course list contains a separate description of each course.

The description of the intended learning outcomes covers the entire program including two specializations; Electrical Engineering and Information Technology. The description (157 words) also briefly explains the structure of the program. The learning outcomes are discussed in a general way covering the competencies connected to the program. That is, it seems that the learning statements have not been formulated using Bloom's taxonomy or a related model. The learning outcomes cover fundamental engineering knowledge, subject-specific knowledge areas, analytical problem-solving skills, as well as communication competencies. Also, project management skills, international competencies, and the ability for life-long learning are mentioned. For example, the core subject-specific competencies are described as follows:

> *"In addition, the graduate of the specialization in Information Technology has knowledge in the fundamentals of Programming Methods, Software Architecture, and Software Engineering."*

University of Jyväskylä (JYU): Information and Software Engineering

The study guide (curriculum) description (University of Jyväskylä, 2021) contains a short (153 words in Finnish) general description introducing the vision and mission of the program as well as the central goals, structure, and contents of the program. This description is followed by the program-level intended learning outcomes that have been written as a list of statements following the principles of a Bloom-style taxonomy. In addition to these sections, the curriculum contains basic data of the program (degree, extent, the language of instruction, etc.) and a course list that links to a separate description of each module or course.

The intended learning outcome definition contains three core learning statements describing the overall learning goals of the education. These are followed by seven additional statements that focus on the specific intended learning outcomes required to meet the overall goals. The length of the learning outcome section in total is 108 words (in Finnish). Examples of the text:

Description part: "*…In addition to the immediate professional competencies, the degree program produces a foundation to life-long learning that is needed to develop one's knowledge and skills during the career. The immediate professional competencies include technological contents, as well as skills to work in a multidisciplinary team to reach common objectives, communication and collaboration skills, and cultural knowledge."*

Core learning outcome example: The graduate is able to *"…approach problems flexibly and act in situations in which the solutions are searched in the interfaces of human activities and technology."*

Additional learning outcome examples: The graduate is able to *"…design and implement IT systems; …recognize the significance of logical reasoning and Mathematics."*

University of Oulu (UO): Computer Science and Engineering

The study guide (curriculum) description (University of Oulu, 2020) contains a general description covering both the B.Sc. and M.Sc. phases of the Computer Science and Engineering program. The description includes 14 sections of which some contain generic content valid for both phases of the program and some are further divided into subsections for the Bachelor's and Master's parts separately. The description (in total 918 words in Finnish) seems to follow the structure of the Finnish national admission system data model and it covers the basic facts of the education, learning outcomes, contents, and structure of the program.

First, the description of the intended learning outcomes discusses the general focus and competence areas. Thereafter, the specific learning outcomes for the Bachelor's and Master's phases are presented as sets of learning sentences using a Bloom-style taxonomy. The Bachelor-level outcome definition consists of seven learning statements. Only one of these statements focuses directly on subject-specific competencies whereas three statements describe different communication and social skills. Other statements cover critical and creative thinking, teamwork, and life-long learning. The subject-specific competencies are approached as follows:

Introductory text:"*…The degree program focuses on providing pervasive skills needed in research, development, and production of IT devices, services and systems."*

Learning outcome example: The [B.Sc.] graduate *"…understands and is able to explain the central principles, methods, and technologies of Computer Science."*

University of Turku (UTU): Information and Communication Technology

The study guide (curriculum) description (University of Turku, 2020) contains a general introductory chapter entitled *Information on the Studies* that includes two sections: *Description* and *Learning Outcomes*. The description is accompanied by a course list that contains a separate description of each course (learning outcomes, contents + possible additional details).

The description (in total 585 words in Finnish) introduces the program goals, contents, and structure. In addition, it provides information on the learning and teaching methods, international student exchange opportunities, possibilities to select courses from other higher education institutions, and explains paths to continue to the Master's studies. Although this description is connected to the Bachelor's degree program, the content seems to be partly written from the Master's perspective. The description section discusses also the general-level learning outcomes but they have not been formulated using Bloom's taxonomy-styled statements. The section Learning Outcomes seems to be a short (29 words) complement of the description summarizing the key learning areas. Examples from the text:

> Description section:"*…The graduating M.Sc. (Tech.) is an expert in Information and Communication Technology who has good ability to apply theory and solve problems, good communication skills, as well as readiness to develop innovative products and services in the key areas of the information society."*

> Learning outcomes section (complete text): "*In addition to the technological contents, the degree program pays attention to the development of working-life skills for the future career. Especially, the following skills and abilities are developed and strengthened: Problem-solving skills, Application of theory to praxis, Project management skills, Teamwork, and Communication skills."*

Åbo Akademi University (ÅAU): Computer Engineering

The study guide (curriculum) description (Åbo Akademi University, 2020) consists of a list of courses. The course list links to a separate description of each course (learning outcomes, contents + possible additional details). However, there is neither a general description of the program nor a list of the program-level intended learning outcomes available. Yet, the study guide seems to contain the possibility to include a program description. Most of the Bachelor's programs at ÅAU contain a short general program description and some, e.g. the B.Sc. in Economics, a longer description including a definition of the intended learning outcomes, too.

The homepage of the program contains a short section that discusses the goals and learning areas of the program (in Swedish: https://www.abo.fi/utbildningslinjer/informationsteknologi/) but no specific intended learning outcomes are defined there either. This paragraph (87 words) binds the subject knowledge to the creation of solutions for the needs of the society and business, mentions analytical problem-solving skills, as well as communication and leadership competencies. An example of the description:

> "…*During the education, you will become a skillful problem solver that is able to combine analytical, technological, and economical knowledge to find optimal solutions for society and business life.*"

BIOGRAPHICAL INFORMATION

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DEVELOPMENT OF ENGINEERING WORKSPACES FOR HANDS-ON AND PROJECT-BASED LEARNING

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ABSTRACT

Surgut State University joined the CDIO initiative in June 2017. Since then 1-5 CDIO standards have been implemented in Bachelor's program on Chemistry. In March 2018 the process of sixth standard (Engineering Workspaces) implementation was initiated. Traditional learning spaces have been created in Surgut State University (SurGU) since 1998. They support the learning of chemical substances, processes, systems and technologies. The creation of new workspaces or remodeling of existing laboratories, in which students are directly engaged in their own learning, as well as providing them with opportunities for social learning and settings where students can learn from each other and interact with several groups is needed to encourage hands-on learning. For these purposes three research laboratories at the Department of Chemistry have been remodeled since 2016, in which several projects, aimed at the investigation of oil composition, source rocks organic matter and biologically active substances from plant materials of Western Siberia, are being realized for last three years. Two laboratories have been created as new workspaces for students' project activity in the ongoing projects since 2018, namely Local Farm, focusing on the chemical monitoring of plants grown in hydroponic sets under agrophotonic conditions, and Drilling Fluids, aiming at the optimization of drilling fluid compositions under the geological conditions of formation. Moreover, university halls have been furnished with individual and co-working spaces and recreation areas. Also a Boiling Point was established in 2019 as a public space convenient for both students and teachers to develop future projects, to organize educational events or participate in ones. Everyone can organize an educational event here or take part in it. Thus new or existing workspaces have been created (or remodeled) at Surgut University for the last 4 years to emphasize hands-on learning and project activity of students in Bachelor's program on Chemistry.

KEYWORDS

Engineering workspaces, project activity, hands-on learning, Standards: 3, 5, 6

INTRODUCTION

Surgut State University joined the CDIO initiative in June 2017. Since then 1-5 CDIO standards were implemented in Bachelor's program on Chemistry (Petrova et al., 2018; Petrova et al., 2019). In March 2018 the process of sixth standard (Engineering workspaces – CDIO workspaces and laboratories that support and encourage hands-on learning of product and system building, disciplinary knowledge, and social learning) implementation was initiated.
The workspace, or learning environment, includes traditional learning spaces, such as classrooms, lecture halls, and seminar rooms, as well as engineering workspaces and laboratories (Crawley, 2013). Workspaces and laboratories support the learning of product and system building skills concurrently with disciplinary knowledge. They emphasize hands-on learning in which students are directly engaged in their own learning, and provide opportunities for social learning, that is, settings where students can learn from each other and interact with several groups. Students who have access to modern engineering tools, software and laboratories have opportunities to develop the knowledge, skills and attitudes that support product and system building competencies (Crawley, 2001). These competencies are best developed in workspaces that are student-centered, user-friendly, accessible and interactive.
Consequently, workspaces and other learning environments that support hands-on learning are fundamental resources for learning the process of designing, building, and testing products and systems. The creation of new workspaces, or remodeling of existing laboratories, will vary with the size of the program and resources of the university. The purpose of this work was the CDIO standard 6 implementation by remodeling and creating of the workspaces and laboratories for chemistry students.

WORKSPACE REMODELING IN SURGUT UNIVERSITY

The traditional learning environment has been developed at Surgut State University since 1998. Over 15 years, a sufficient number of workspaces tooled up with modern engineering equipment has been created in the university, including classrooms, lecture and sport halls, located in four campus buildings, as well as seven research laboratories of the Chemistry department. The latter ones encourage students of Chemistry Bachelor's program to study chemical substances, processes, systems and technologies aimed at the development of professional skills in the field of inorganic, organic, analytical, physical, oil chemistry and other disciplines.

The creation of new workspaces and remodeling of existing laboratories, in which students are directly engaged in their own learning, as well as providing them with opportunities for social learning and interaction is needed to encourage hands-on learning and support student project activities. For these purposes three research laboratories of the Chemistry Department have been remodeled since 2016, namely: (1) thermal methods of analysis; (2) spectral methods of analysis and (3) sample preparation and petrochemical synthesis. The laboratory of thermal analysis methods (20 m^2), for instance, may be used for simultaneous lectures, seminars, as well as a teamwork experimental research, conducted by a student group of 6-8 people under the supervision of 1-2 teachers. In particular, several projects, aimed at the investigation of oil composition, source rocks organic matter and biologically active substances from plant materials of Western Siberia, have been realized in the mentioned workspaces over the last three years. Furthermore, university halls have been furnished with a number of co-working and recreation areas.

Thus, all the mentioned workspaces, appeared at the university, are affordable, interactive, convenient and student-friendly. In three remodeled laboratories, students of 1-2 courses on Chemistry (~30 per year) are engaged in project activities, and students of 3-5 courses (~50 per year) carry out coursework projects and theses, and also conduct research.

NEW WORKSPACE CREATING IN SURGUT UNIVERSITY

To ensure high levels of faculty, staff, and student satisfaction with the workspaces new workspaces, namely Surgut State University Boiling Point (BP SurGU), Local Farm and Drilling Fluids laboratories, have been created in the university since 2018.

The university Boiling Point is a developing space, convenient for students and teachers to work together on the future projects, regularly organize educational events or take part in them. The involvement of leaders and talents enable participants to quickly test breakthrough ideas, assemble project teams, find like-minded people, learn, teach, bring a positive impact on the life of a university, city, region or country – make the world a better place. On October 19, 2019, during the Autumn Navigator session, 41 university co-working spaces (Boiling Points) were opened in 33 Russian cities, including Surgut in Surgut State University. The total number of Boiling Points in the network of the Agency for Strategic Initiatives (ASI) now reaches 82.
A lot of events: conferences, round tables, workshops, master classes, project and pitch sessions took place in the BP SurGU with the participation of more than 200 people, including staff, scientists and university chemical students. On October 24, 2019 a pitch session for bachelors, undergraduate and graduate students in the areas of natural sciences was organized in BP SurGU during the conference «Save North – clean Arctic», with the time limit (no more than 5 minutes) and the presentation template (no more than 3 slides) announced. In total, more than 30 reports were recorded, but only 18 were selected for speeches. As the outcomes of the event showed that the pitch session helped students to develop cross-cutting competencies, such as the ability to present their own research and teamwork results, answer the questions and lead discussions.

In July 2018 the university in a business partnership with REATONIKA Company established a new learning space for the project activities of undergraduate Biology and Chemistry students – the Local Farm Laboratory. REATONIKA Company is manufacturer of hydroponic systems, including for the cultivation of green and essential oil crops, in the North-West of the European part of Russia and in Western Siberia. The company operates in the field of biotechnology.

The purpose of the created laboratory is to implement a joint project between SurGU and REATONIKA, aimed at developing a Local Farm – an affordable technology for growing crops in closed ground under artificial lighting and introducing an intelligent management system of the local farm resource. Students' involvement in this case includes course works and theses performance; academic, industrial and research practices, making a learning process fully integrated into university's scientific and business projects.

The laboratory consists of three small rooms: (1) for preparing fertilizer solutions; (2) for seed germination; (3) for growing green crops in hydroponic installations with LED lighting systems. All necessary equipment, seeds, fertilizers, substrates for hydroponic sets and other supplies were provided by a business partner. Chemistry program students participate in the project by chemical monitoring source water and fertilizer solutions, used in hydroponic installations and grown products. For chemical analysis the equipment of Chemistry Department and University

Collective Center is used (Figure 1). The Local Farm Lab is practically used for practical, active student and project learning in Analytical and Organic Chemistry courses and Project Activity of 1-3 year students. Chemistry students are actively involved in the preparation of recommendations for fertilizer solutions by order of the REATONIKA Company. They regularly participate in working meetings with company management and present research results.

In May 2018, on the 25th anniversary of the Surgut State University, it was decided to establish the university Competence Center of Drilling Fluids research (CC LDF), with the financial support of PJSC Surgutneftegaz – a major oil company in Western Siberia. According to the company governance, the establishment of such laboratory is to improve the learning process and chemists training quality. More than 40% graduates of Bachelor's program in Chemistry and integrated Magister's program in Fundamental and Applied Chemistry are traditionally employed in the chemical laboratories of Surgutneftegaz. In addition, the creation of Drilling Fluid Laboratory would bring an ongoing research to a higher level, increase the commercialization of scientific results and the development of university innovative activity. The laboratory is planned to be used as an R&D center, where new reagents based on surfactants, nanocomposites and layered materials would be developed. Another objective of the CC LDF lies in optimization of drilling fluid formulation under the geological conditions of hard-to-recover reserve fields.

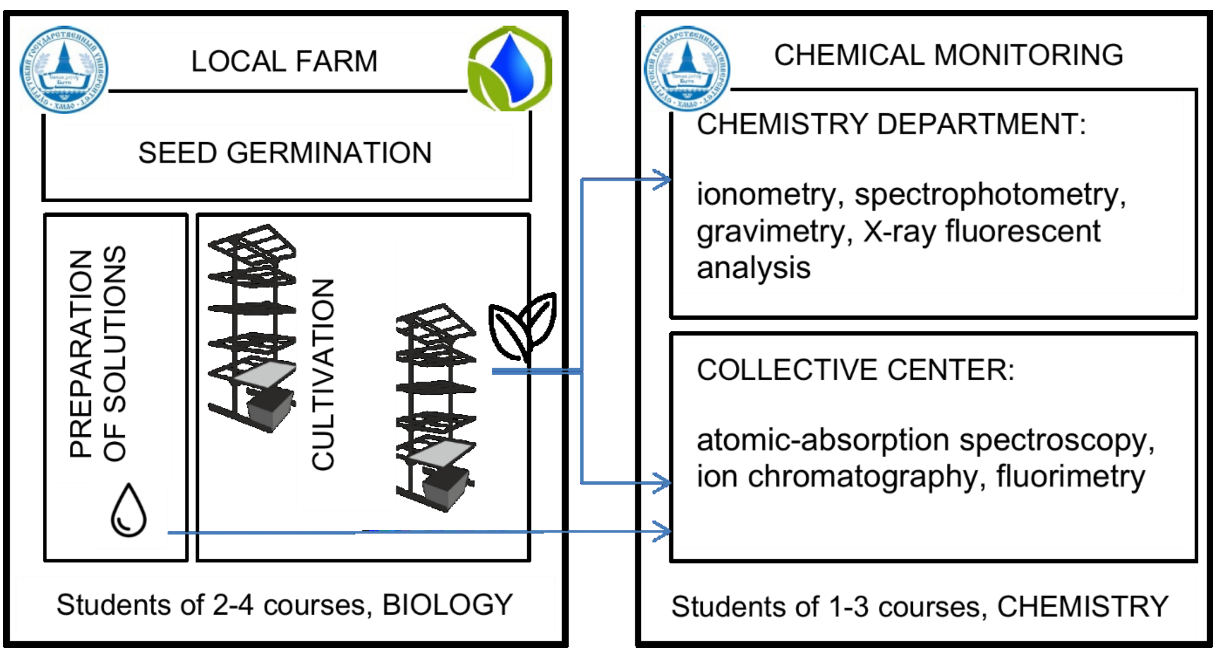

Figure 1. Scheme of student project activities at the Local Farm

Surgutneftegaz has provided funding for the purchase of laboratory equipment, such as a rotational viscometer, a high-pressure filter press and a temperature laboratory blender, and furniture. The laboratory design was completed with the creation of a space for student project work (Figure 2). In the center of the laboratory, there are island tables for teamwork, which may include planning and discussing the experimental processes, project tasks assignment, results recording and presentation, consultations of a supervisor and etc. Specialized equipment is planned to be placed on tables near the walls, in the cabinet between windows – reagents and laboratory glassware. Altogether such workplace is capable of simultaneously accommodating no more than 12 students, working individually or as team members.

In the future the database of CC LDF laboratory studies, based on the accumulated historical data and real-time data, will allow to develop domestic visualization tools and predictive analytics, to solve the priority tasks of the Ugra oil and gas cluster with the assistance of the Competence Centers of National Technological Initiative (CC NTI) «New Production Technologies» (Peter the Great St. Petersburg Polytechnic University) and «Technology for Storage and Analysis of Big Data» (M.V.Lomonosov Moscow State University), as well as other partners.

a) *b)*

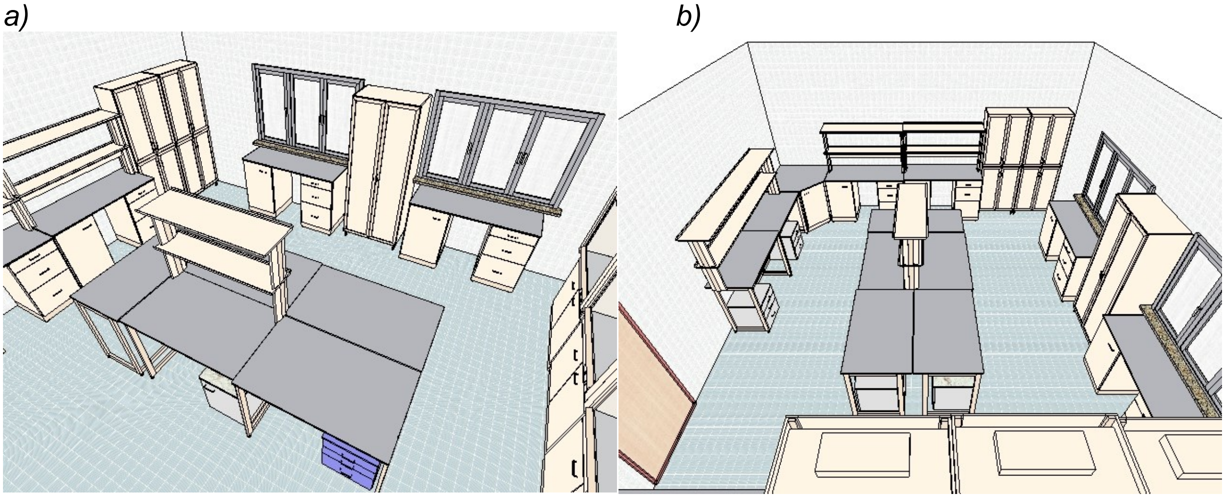

Figure 2. The laboratory design of Drilling Fluid Laboratory:
a) direct view; b) side view

In 2020 the Mirror Engineering Center of CC NTI «New Production Technologies» (Peter the Great St. Petersburg Polytechnic University) on the basis of Surgut State University was created. The aims of this Center in project learning activity are:
- the development of approaches to digital certification based on virtual tests, which will replace some expensive laboratory tests with virtual ones;
- the development of application software and a virtual test bench "Drilling fluid", which is supposed to be used for virtual optimization of recipes and training for students.

In 2021-2023 the project «Digital Twin of Drilling Fluid» (Figure 3) is planned for implementation with the participation of chemistry students.
Mirror Engineering Center of St. Petersburg Polytechnic University at Surgut State University will be a regional center of competence in the direction of «New Production Technologies» (NTI), which will contribute to:
- enhancing the competencies of digital modeling and digital design based on digital twins and providing student projects in the field of digital engineering;
- the development of cooperation with industrial partners (expanding the portfolio of customers and expanding the list of proposals for industrial partners);
- raising the competence level of staff and students in the field of «New production technologies», including due to the development of project-oriented learning methods;
- increasing the attractiveness of the university and the demand of graduates in the labor market.

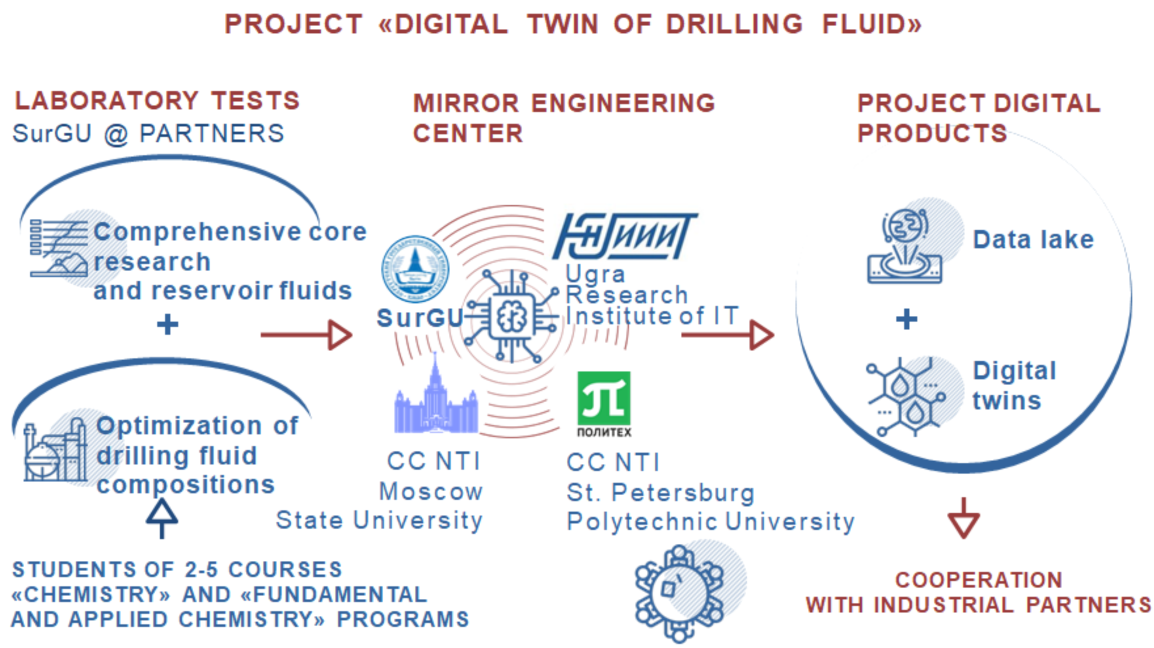

Figure 3. Project structure «Digital twin of drilling fluid»

CONCLUSION

Thus, in accordance with the standard 6: CDIO workspaces and laboratories that support and encourage hands-on learning of product and system building, disciplinary knowledge, and social learning were remodeled and created in Surgut University since 2018. At the university the student-friendly workspaces have been appeared for project activity, co-working and recreation. New learning spaces – laboratories Local Farm and Laboratory of Drilling Fluids were organized at the university for students in Chemistry with support business and industrial partners.

The implementation of redesigned laboratory workspace had allowed us to improve such learning outcomes as teamwork; design process; verification, validation, and certification; implementation management, and had also improved communications; experimentation, research and knowledge discovery; ethics, equity and other responsibilities. The student satisfactions of remodeled and created workspace were assessed before and after implementation using common indicators of learning process satisfaction. A survey of students in February 2020 showed that more than 36% of respondents considered SurGU graduates as competitive (earlier in 2018 it was difficult to answer), more than 54% were satisfied with acquired skills level (up to 40% before implementation). More than 69% of respondents in 2020 said they did not have enough practical skills (in 2018 there were more than 75%), and 29% - the life and career planning skills (40% previously).

Boiling Point was opened in Surgut at Surgut State University on October 19, 2019 as a developing space convenient for students and teachers to work together on the future projects.

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CDIO APPROACH TO WRITE REFERENCE MODELS FOR TRAINING DECISION SKILLS

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ABSTRACT

Preparing engineering students for the future is becoming increasingly challenging as the pace in world and business environment escalates. The CDIO initiative provides curriculum designers and faculty with a template that stress the fundamental attributes that engineering graduates should possess when they enter the workplace. As discussed in this article, the template can also be applied as a framework to set forth educational guidelines on a particular subject. In particular this article examines how the CDIO methodological approach is applied to mature a procedure for enhancing certain managerial skills. The procedure is aimed to guide educational institutions how to implement training on judgement and decision-making skills in situations that are volatile, uncertain, complex, and ambiguous (VUCA). The outcome presents seven essential and successive decision skills that are to be adopted in the curriculum. The curriculum development is progressed via six stage-based reference models (6RM). Each of the six reference models constitutes the set of criteria needed for the implementation and adaption of the required change processes. Furthermore, each reference model comes with a rubric for a self-assessment on the current maturity of a VUCA based educational program. The point position to communicate the seven decision skills and other managerial challenges to address can also be scaled with the 6RM. The seven decision skills and the Six Reference Models are the offspring of the Erasmus+ funded program Dahoy that started in 2017 and completed in 2020. The 6RM were tested as a pilot study at the Engineering Department of Reykjavik University in 2020 with positive results.

KEYWORDS

Decision making, reference models, curriculum, Dahoy, Standards: 1-12.

INTRODUCTION

The context of this paper is how the CDIO guidelines, standards, and rubrics, can be applied to constitute a comprehensive reference model for establishing and developing an educational program in the academic field of decision analysis under conditions of uncertainty. The undercurrent of this endeavour is the increasingly complex world engineers must work and thrive. Whether they are to act as experts on environmental issues, technology, engineering, national emergency or other fields, future decision makers should also be specifically prepared to making decisions in what is named the VUCA environments (i.e. Volatile, Uncertain, Complex, and Ambiguous). The VUCA concept has been used earlier as platform to enhance engineering and other educational structures see for example Latha and Prabu (2020), Rouvrais, Gaultier Lebris and Stewart (2018) and Seow, Pan and Koh (2019).

Decision is a complex concept, with multiple dimensions. For engineers, decision making echoes in scientific methods (e.g. math-based), human environment (e.g. social-based), or even in professional pathways and development (e.g. career-based), or even in professional pathways and development (e.g. career-based).

The field of decision analysis, first introduced by Raiffa and Schlaifer (1961), was originally mostly a mathematical discipline, but it has evolved into a useful method for industry and government. Math-based decision-making methods have their limits. People are not always rational and are affected by cognitive and behavioural aspects that might e.g., limit the use of statistical analysis. In later years the seminal work of Daniel Kahneman and Amons Tversky on how cognitive biases influence our behaviour shape our decision-making has become instrumental part of decision theory see e.g. Kahneman and Tversky (1979). It is also worth mentioning the work of Taleb (2007) on what he calls black swan events, i.e. extreme events with low probability and high impact the covid-19 pandemic being a perfect example. This decision problem has e.g., been addressed in studies by Fridgeirsson et al. (2021) using the VUCA concept to capture risk influences in decision-making. The axioms of decision analysis will not be discussed any further, but a reference made to the authors publication see Gaultier et al. (2017). The attributes of the seven decision skills accounted for later in the text are products of decision making in context of the mathematical and social sciences briefly mentioned earlier in this section.

To stimulate pedagogical innovation in training decision making skills in VUCA-like situations the project D'Ahoy was initiated. The project was named Decision Ship Dahoy (a reference to A. G. Bell, the Scottish-born scientist who patented the first telephone and originally suggested 'Ahoy' as the standard greeting when answering a call) and was funded by the Erasmus+ program for the period 2017-2020. The main instigator of the project was Dr. Siegfried Rouvrais of the IMT Atlantique – Télécom Bretagne (France). Other participants in developing the scheme were from Ecole Navale (France), COGC (Scotland), SCQF (Scotland) and Reykjavik University (Iceland).

From the beginning the CDIO Initiative inspired the academics and professionals working on the Dahoy project. In the CDIO Syllabus (see www.cdio.org), Decision Analysis with uncertainty (ref. 2.1.4) and initiative and willingness to make decisions in the face of uncertainty (ref. 2.4.1) are requirements for personal and professional skills. Making complex technical decisions with uncertain and incomplete information is also a CDIO requirement for exercising judgment and critical reasoning (ref. 4.7.7).

The CDIO standards are designed to be a framework for complete engineering programs. The research questions in this study are firstly if and how the CDIO framework and standards can be applied and adapted to specific subject within an engineering program, in this case to train decision making skills in VUCA-like environment. The adaptation was developed during the course of the three-year Dahoy-project. Secondly, as an evaluation of the proposed adaptation, we present a case study where we apply it to the first year of engineering at Reykjavik University, which offers a traditional education in engineering.

This paper is segmented in firstly describing the Dahoy project, then how the project outcomes comply with the CDIO standards. Then we introduce rubrics for assessing the levels of curriculum maturity of an educational institute. Lastly, the reference model is put in practice by assessing an engineering program and the compliance of a teaching event towards the skillsets derived from the Dahoy project.

DECISION MAKING SKILLS AND THE DAHOY PROJECT

The objective of the Dahoy project was “to create inclusive, active and experiential pedagogies for better Decision-Making skills in VUCA situations, so as to render education systems more accessible and attractive” (Dahoy, 2018). The foundation for the Dahoy project were fundamentals theories in Decision Making. Rouvrais et al. (2020) discussed and argued for training of decision-making skills in a VUCA-like situations.

The Dahoy project empathizes that students understand the scope and limitations of mathematical decision-making methods and of computing tools. The VUCA approach to decision making is intended to enhance the student´s decision skills by adding elements of social sciences. Noteworthy in this respect are learning to recognize cognitive biases, utility-based decision modelling, scenario planning, etc. The authors like also to refer to a previous publication for more detailed orientation (Gaultier et al., 2017). Moreover, the decision skills to arrange and development future career were included in the program. The three perspectives of decision skills that were considered,(i) math-based, (ii) social-based, and (iii) career-based, are shown in Figure 1.

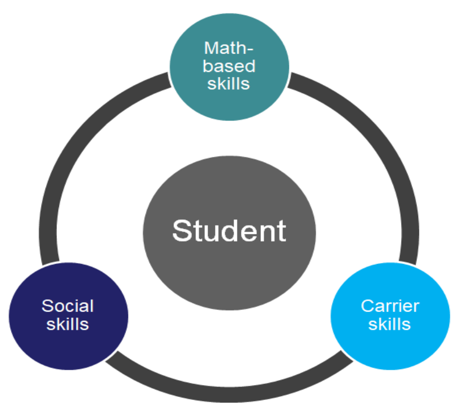

Figure 1. The interconnected skillsets of the Dahoy academic perimeter (Dahoy, 2018).

The realization of the objective of the Dahoy project was the writing of reference models and maturity assessment model for educational institutions. Reference models are useful to create standards to define the desired qualities and the benchmark for maturity. Furthermore, to stress the challenges of the change process and improve communications among the stakeholders. Moreover, to outline the entities of the concept and the applicable strategies for implementation. The authors acknowledge that the use of the term “reference model” might cause misperception, as this term is more traditionally associated with the realm of software development. However, this was the term selected for use in the Dahoy project and is applied in this study for the sake of consistency.

DEVELOPING STUDY LINES

Successfully developing a study line or a particular theme that is to be integrated in several courses within a study line, is based on careful planning and continual revision. The course goals must be clear and well documented in the learning outcomes, consistent with the overall outcome of the study line, the pedagogy must be strongly connected to the learning outcomes followed by the courses content and teaching methods. There are three methods of course design that are commonly used, i.e. forward, central, and backward (Richards, 2013). Other models worth mentioning are Dick and Carrey, Kemp, and Three Phases models (Kusrini 2018)

The CDIO initiative has been successful in revising and aiding in continued development of engineering education worldwide (www.cdio.org), and the experiential learning pedagogy is both implied and explicit in the CDIO paradigm and standards. In the Dahoy-project there was interest in applying the CDIO approach, standards, and rubrics, as a guiding light in implementing a program in training decision skills.

THE PROGRESSION OF THE DAHOY

Reference Models

The writing partners in the Dahoy-project were provided with guidelines based on the CDIO Initiative approach of writing standards. The writing guidelines ensured that the results were presented in a consistent mode. Overall, six reference models (RM) were composed as Figure 2 shows.

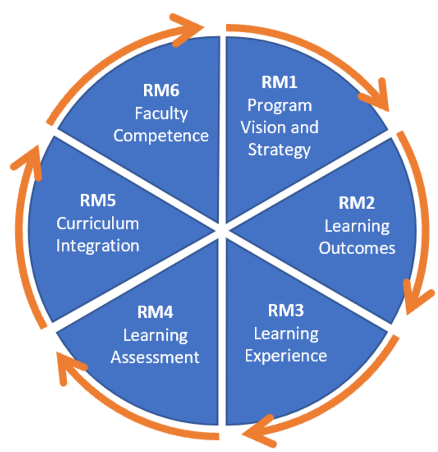

Figure 2. The Dahoy Reference Models (RM) (Dahoy, 2020).

Table 1 shows the correspondence between the Dahoy-RM and the CDIO-standards. The table shows explicitly how the standards were used as a template for establishing an educational program within an already established engineering program, or for a management program for that matter. Although the standards are used here as a template for the field of training decision-making, it might as well be used for other subdisciplines of engineering. The CDIO-standards used were on stating the philosophy of the educational program (1), learning outcomes (2), on the teaching and learning process (7, 8, 11), and on faculty development (9, 10). Four out of the 12 standards were not used, 3, 4, 5 and 6, as they were not relevant for training decision making.

Table 1. The six reference models (RM) as developed in the Dahoy-project and the corresponding CDIO-standards V3.0 (Dahoy, 2020) and (CDIO, 2020).

RM	CDIO
RM References for curriculum development specific for training decision skills in VUCA-like situations.	CDIO Comprehensive standards describing engineering programs committed to the CDIO philosophy.
RM1 Context Establish programme vision and strategy to include training and teaching decision analysis in VUCA situations and facilitate support from program leaders to sustain reform initiatives at higher institutional level.	1 Context. Adoption of the principle that sustainable product, process, system, and service lifecycle development and deployment – Conceiving, Designing, Implementing and Operating – are the context for engineering education. 12. Program Evaluation. A system that evaluates programs against these twelve standards and any optional standards adopted, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement.
RM2 Learning Outcomes Include the seven decision-making skills in the learning outcomes of the program and put them in the context of activities that are complex and where there is unpredictive change.	2 Learning Outcomes Specific, detailed learning outcomes for personal and interpersonal skills, and product, process, system, and service building skills, as well as disciplinary knowledge, consistent with program goals and validated by program stakeholders.
	Standards not used: 3, 4, 5 and 6
RM3 Learning Experience Training in decision making should be based on three components, mathematical, social and career, with variable intensity and complexity. The training can be implemented by standalone modules or integrated in transversal courses modules or courses. Emphasis is on experiential learning.	7 Integrated Learning Experience Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, and product, process, system, and service building skill. 8 Active Learning Teaching and learning based on active and experiential learning methods.
RM4 Learning Assessment Assessments should evaluate the skill sets acquired by students by participating in the relevant activities and modules and should reinforce reflection of activities.	8 Active Learning Teaching and learning based on active and experiential learning methods. 11 Learning Assessment Assessment of student learning in personal and interpersonal skills, and product, process, system, and service building skills,as well as in disciplinary knowledge.
RM5 Curriculum Integration The curriculum should be enriched by integrating decision making skills, emphasizing methods and processes.	10 Enhancement of Faculty Teaching Competence Actions that enhance faculty competence in providing integrated learning experiences, in using active and experiential learning methods, and in assessing student learning.
RM6 Faculty Competence The educational programs should commit adequate resources for staff development and training.	9 Enhancement of Faculty Competence Actions that enhance faculty competence in personal and interpersonal skills, product, process, system, and service building skills, as well as disciplinary fundamentals. 10 Enhancement of Faculty Teaching Competence Actions that enhance faculty competence in providing integrated learning experiences, in using active and experiential learning methods, and in assessing student learning.

Each RM entity (as outlined in Table 1 and Figure 2) consists of:

- *Introduction:* The content of the RM section and give information on why the section is needed as well as background information if applicable.
- *Goal:* A goal describes the educational institute edifying decision skills should expect or hopes to accomplish strategically, tactically and/or operationally over a specific period by the respective RM.
- *Stakeholders:* In education, the term stakeholder typically refers to anyone who is invested in the welfare and success of a school and its students, including administrators, teachers, staff members, students, parents, families, community members, local business leaders, and elected officials such as school board members, city councillors, and state representatives. Stakeholders may also be other collective entities. Each section should identify the main stakeholders the respective RM concerns and the role of the stakeholder.
- *Description:* The Description should explain the scope of the respective RM, i.e. it should describes what the corresponding RM section does.
- *Rationale:* Rationale describes the underlying basis for the RM and should list exactly what the educational institute to do to use/deploy the corresponding RM for the purpose of edifying decision skills.

Maturity Rubrics

The 6RM´s are supported by a maturity rubric to sustain the progression of developing the program. The role model for the maturity assessment is the CDIO generic rubric applied to each of the 12 CDIO standards. Each RM can be rated based on a self-assessment and for demonstration the rubric for RM1 (context) is shown in Table 2:

Table 2. Example of a maturity rubric for the first Reference Model, RM1 (The context) (Dahoy, 2020).

Level	Maturity level
1	There exists no plans to incur VUCA principles in the visions and missions of the University, nor teaching agenda in the foreseeable future on decision skills in these contexts
2	There is an institutional vision stated, and documented plan or activity related to the VUCA criteria in the school for teaching and training purposes. Interest among stakeholders but consolidated activities and functions are missing.
3	There is an awareness of the needs of how to adopt the VUCA teaching criteria and a plan, validated with key stakeholders, is formalised and a process is in place to address them and direct activities are work in progress.
4	There is a plan implemented in place to address the VUCA criteria for teaching and some VUCA activities are in function as part of the teaching schedule and the syllabus, across the curriculum. VUCA advocates are among the faculty.
5	The VUCA statements and decision programme outcomes are formalised in the institution's strategic documents. There is documented evidence of the full implementation and impact of the VUCA based teaching strategy across programme components and several VUCA activities for decision skills reinforcement are in function. A clear emphasis on VUCA teaching consolidated in the syllabus and among faculty members is visible and verifiable
6	Evidence related to the VUCA based teaching strategy is regularly reviewed according to the missions of the institution and its strategic plans, and used to make continuous improvements. VUCA is teaching as core competence in the graduates' profiles in the syllabus.

Testing the Model

The 6RMs were applied at the Department of Engineering at Reykjavik University to assess the current maturity of decision skills teaching and learning in the context of the project. The Department of Engineering is a member of the CDIO initiative as over 100 other progressive universities. A grid was arranged, and the maturity of the scheme evaluated subjectively by two experienced faculty members. Apparently, the six reference models appear to be a useful indicator of the level of maturity and a realistic platform for further development of the teaching and learning programme. Table 3 shows the results of the current state. The level numbering refers to the textual description of the maturity in the context of the respective RM.

The assessment was carried out via expert panel consisting of faculty members. The RM´s were deemed as usable to assess current state of teaching in context of the Dahoy program. Moreover, the model gives decent indication on the tasks needed to develop the curriculum towards VUCA based teaching Decision Analysis based on mathematical and social principles.

Table 3. Assessment of the maturity of the 1st year engineering program at Reykjavik University.

RU 1´ST YEAR ENGINEERING PROGRAM		
REFERENCE MODEL MATURITY ASSESSMENT GRID		
Reference Models	**Level**	**Explanation**
RM1 – Context	3	There is an awareness on the needs of how to adopt the VUCA teaching criteria' s and a plan, validated with key stakeholders, is formalized and a process is in place to address them and direct activities are work in progress.
RM2 – Learning outcomes	2	There is some reference to decision skills and/or VUCA capabilities in the programme outcomes or in a graduate profile.
RM3 – Learning experience	3	Active or experiential learning methods for decision skills is being implemented across the curriculum including the VUCA dimensions.
RM 4- Learning assessment	3	There are summative assessments in place for all VUCA activities and decisions skills related T&L, and there are actions in a plan (?) in place to include formative assessments.
RM5- Curriculum integration	2	The need to analyse the curriculum along VUCA dimensions is recognized and initial mapping of transversal decision skills learning outcomes is underway.
RM6 – Faculty competence	2	A benchmarking study and needs analysis of faculty competence and faculty teaching competence has been conducted on Decisions Skills.

Dahoy-Project Outcomes

Firstly, seven skill statements were identified in the Dahoy-project that learners of decision making under uncertainty should be capable of. These are listed in Table 4. These skills are mirrored in the 6RM's and the respective maturity rubrics as applicable. Furthermore, other more site-specific factors like the managerial challenges, stakeholder identification, change processes, curriculum development, faculty integration are addressed with references to EU and national doctrines as possible.

The compliance of certain teaching event towards the seven decision skills can also be assessed. The authors assessed the event "Disaster Days" by a compliance grid, see Table The engineering programmes at Reykjavik University (RU) have since 2011 run a two-day intensive course, Disaster Days (DD), early in the first semester (Audunsson, Fridgeirsson and Saemundsdottir, 2018). The context of the project in "Disaster Days" is an unexpected challenge that must be dealt with in teams in a single day, and each team must make decisions in a VUCA-like situations. The DD endeavour was originally developed to introduce freshly enrolled students at Reykjavik University to alternative teaching methods in line with the experiential learning strategy. The DD also turned out to be a success on connecting students and forming social relationships that contributed to the learning progression of the student during his stay at RU. The original concept did not include the VUCA idea directly although the relationship was apparent. The DD as a test case to audit the "VUCA-lity" of the DD teaching event was therefore interesting to the content creators that are supposed to bring on new and innovative challenges each year. The audit turned out to give realistic results on the current state of VUCA'lity and indicate how the event could be improved.

Table 4. Compliance to a particular educational event based on the seven decision skills that were identified in the Dahoy-project.

RU 1´ST YEAR ENGINEERING PROGRAM - DISASTER DAYS				
VUCA ASSESSMENT GRID				
DECISION SKILLS	**V**	**U**	**C**	**A**
D1 - Recognize and qualify a VUCA situation	Medium	High	Medium	High
D2 - Analyse a situation	High	Medium	High	High
D3 - Make a judgment	Medium	High	Medium	Medium
D4 - Face complexity	Medium	Medium	Low	Medium
D5 - Organize and implement actions	High	Low	Medium	None
D6 - Take a responsibility of a DM process	Low	Low	Medium	None
D7 - Learn from experience	Low	Low	Low	Low

DISCUSSION

Of many schemes of developing and implementing new study lines or courses (e.g. Richards, 2013), we felt it was appropriate and worthwhile to apply the CDIO standards in the specific case of implementing the training of decision making skills for engineering students. Above we presented the reference models (RM) and maturity rubrics developed in the Dahoy-project, both of which were based on the standards and rubrics resulting from the CDIO approach. The CDIO standards provided the Dahoy partners with excellent platform to make the work effective and efficient. The outcome in the form of Reference Models, skillsets and Maturity models were tested in real life by auditing an engineering program and experiential teaching event. The model turned out to be usable in its current state and reflect adequately the academic and managerial challenges for engineering programs planning to teach VUCA based decision skills. However, the 6RM´s are definitely in the first stages and could arguably be simplified and made more accessible for use. In short, as an answer to the main research question posed initially, we can conclude that the CDIO framework and standards can be applied and adapted to specific subject within an engineering program, in this case to train decision making skills in VUCA-like environment.

CONCLUSION

The training of engineers should reflect the world in they operate. The VUCA concept is sensible to influence the mind of the engineer towards scenarios characterized by uncertainty and complexity. It is therefore valuable for the developers of curriculum in higher education institutes to have access to references paving the way for VUCA augmented programs. We have outlined how the CDIOstandards and rubrics, were applied to construct a comprehensive reference model for establishing and developing an educational program in the field of decision analysis under VUCA-like conditions. The program on decision making as discussed here is intended to be run within an already established engineering program, such that only a part of the CDIO-standards was needed. It appears that the standards are comprehensive and general enough such that the methodology presented here might be applicable for other educational programs.

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ONLINE TEACHING MODES FROM THE PERSPECTIVE OF CONSTRUCTIVISM

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ABSTRACT

China online education has been developing for more than 20 years, especially since 2013, with the tide of "Internet plus education", online teaching and MOOCs in colleges and universities have been unprecedented popularity, changing the traditional teaching mode and teaching methods. With the outbreak of COVID-19 epidemic in 2020, online teaching has rapidly become an important alternative to in person learning in colleges and universities. Teachers respond quickly and choose different online teaching platforms to carry out online teaching by using the national free open learning resources and their own curriculum resources. Based on the questionnaire survey of the students in E-commerce Department of Dalian Neusoft University of Information, it is found that the online teaching basically meets the teaching needs during the epidemic period. But there are many problems, such as large number of online teaching platforms, insufficient teaching resources, poor experimental teaching experience, traditional teaching mode online, and low interactive quality. Based on the constructivism teaching theory, this paper proposes to integrate teaching platform and enrich platform functions through technology empowerment; to improve teachers' teaching ability through training; to reconstruct teaching content with OBE teaching concept; to design reasonable evaluation methods and timely feedback students' learning effect by means of information technology; to promote online and offline "double line" integration to build a new normal of education and teaching. The purpose of this study is to provide reference for the development of online teaching in colleges and universities, so as to promote the reform of teaching mode and improve the quality of students training.

KEYWORDS

Constructivism, Online teaching, Teaching modes, Standards: 7, 8

INTRODUCTION

With the development of information technology, especially the development of mobile Internet, big data technology and artificial intelligence, people's learning and lifestyle has been profoundly changed. According to the 46th "Statistical Report on the Development of Internet in China", there are 381 million online education users in China, accounting for 40.5% of the total Internet users (CNNIC, 2020). Online education is a teaching method based on network access. China's online education emerged at the end of the 20th century, known as distance learning for adult education and vocational education at that time. After the year 2000, a series of policies were issued by the state to increase the construction of education informatization and promote the reform of education and teaching. Therefore, a large number of excellent courses and excellent resource-sharing courses have been constructed. Especially since 2013, with the tide of Internet plus education, the state has launched a large number of high-quality MOOC resources, which has changed the traditional teaching mode and teaching methods (Xu et al., 2020). With the outbreak of COVID-19 in 2020, the Ministry of education of the People's Republic of China proposed to "suspend classes without suspending teaching, suspend classes without suspending learning", in order to reduce the impact of the epidemic on school teaching (Wu&Yue 2020). College teachers quickly respond by learning and testing the functions of different platforms to seek the best solution to transfer offline courses to online teaching. During the whole epidemic period, although the online teaching design of each course has been carried out, the design concept is still based on the traditional teaching design, which is difficult to effectively arouse the enthusiasm of students. In May 2020, the Ministry of education announced that after the epidemic, online teaching will be normalized. In order to better carry out online teaching in the future, it is necessary to introduce constructivism to explore online teaching modes.

THE CONCEPT OF CONSTRUCTIVISM

According to constructivism, the acquisition of learners' knowledge is not one-way transfer from teachers to students, but through the cooperation and interaction with others by using certain learning resources, and the way of meaning construction. Students who participate in cooperative interaction output their own knowledge, and give their different opinions among members, so that knowledge can be assimilated and adapted in sharing to promote the development of students (Yao, 2003). Constructivism theory emphasizes that the students are the main participants in the research learning process, and students learning is a synthesizing experiencing process of knowledge construction and socializing.
Teachers create a teaching situation for students to stimulate the original knowledge and experience, and link new knowledge, so that students can practice knowledge in various real situations and promote the transfer of knowledge. Constructivist learning theory holds that "situation", "cooperation", "conversation" and "meaning construction" are the four elements of the learning environment. Based on constructivism theory, teaching content, teaching strategies can be reconstructed to form a good environment for online teaching (Gao et al., 2008).

CURRENT SITUATION OF ONLINE TEACHING

This paper investigates the implementation of online teaching of E-commerce Department in Dalian Neusoft University of Information through questionnaire and interview. A total of 384 questionnaires are collected, which can reflect the situation and existing problems of online teaching.

Network Jam

During the epidemic period, all of the schools including the primary schools, middle schools and college schools in China have changed their offline teaching to online teaching, and tens of millions of students accessed to the network at the same time, therefore, the network jam occurred frequently. Due to the network jam, teachers couldn't release online tests successfully, and students couldn't join the virtual classroom by scanning the code and submit their online test and assignment smoothly. Meanwhile, video and sound were not synchronized due to the network delay. Some teachers had no choice but to use an alternative way, using voice and text instead of live broadcast, or recording courses for students to watch after class. Through the questionnaire, 81% of the students regarded network jam as the number one problem during the online learning, which directly affected the students' online learning experience.

Frequently switch platforms

Many colleges give teachers the right to choose their own teaching platform. Due to the imperfect function of online teaching platforms, or limited network traffic access, a platform cannot meet the requirements of teachers' online teaching. Teachers usually choose online teaching platforms according to their own preferences, resulting in a student using different platforms for different courses. Even for the same course, teachers also use multiple platforms to improve their teaching efficiency. Taking Dalian Neusoft University of Information for example, teachers used Dingding, Tencent classroom, Tencent conference, QQ classroom, Chaoxing when they delivered online teaching. When teachers interacted with the students, they used Rain Classroom, Ke tang pai, Wen juan xing, etc. When students submitted homework, the school's homework management platform was utilized. More than 1/3 of the students evaluated that frequently switched platforms made them experienced inadequate learning. Some students complained they missed submitting homework because of the multi-platforms.

Poor experimental teaching experience

The main forms of teachers' online teaching include: live teaching, video + online Q&A, MOOC + online discussion and Q&A, etc. The live teaching mode basically transfers the offline teaching mode online through the online platform. Students can interact with teachers in real time and have a high degree of participation, the live teaching mode are more popular with students than the other forms. At the same time, the teachers record the live teaching video, so that students can repeatedly watch the episodes they do not completely understand to ensure the students' learning effect. 91% of the students are satisfied with the live teaching, especially for the management courses. More than 90% of the students thought that the teaching pace was moderate. But in the computer experiment class, students' satisfaction was low. For experimental courses, if the courses are taught offline, students are usually arranged in a well configured experimental environment. Even if students install the experimental environment by themselves, teachers can provide on-site guidance to solve students' problems in time. While online teaching, even if the teacher provides the video of the experimental operation steps in advance, the students spend the time in studying and practicing independently after class, and the teacher answers the question and solves the problem in class. Students have different computer configurations and it is not so convenient for teachers to provide online guidance as offline guidance, so that some of the students’ problems cannot be solved timely and effectively. For students with poor self-learning ability, they cannot grasp it well.

Insufficient learning resources

Some courses have insufficient teaching resources, only PowerPoints and auxiliary extracurricular reading materials are available for the students. During the epidemic period, students did not go back to school, so they did not have hardcopy textbook. When students encountered knowledge difficulties, it was not easy for them to find learning resources for further study. Due to insufficient learning resources, some teachers used the free MOOC of other schools, but MOOC contents were not completely suitable for students. Students learning abilities are different among schools. Different schools have different teaching orientation, teaching objectives and teaching system, the teacher must choose the appropriate MOOC and reconstruct teaching contents.

Inefficient classroom interaction

Influenced by traditional teaching mode for a long time and lack of design experience of online teaching, it is difficult for teachers to quickly adapt to online teaching in a short time. Teachers usually used platform tools to know students' class performance by online answering questions, bullet screen or quiz. For the class with a large number of students, students replied to a lot of messages in a short time, and some messages were quickly covered, which made it difficult for teachers to pay attention to students' learning feedback. In addition, students had a sense of novelty and participated actively in this form at the beginning. As time went on, the enthusiasm of students had declined and they did not participate in the class interaction as before. A few of the students directly copied other students' answers or searched for the answers online in order to get a formative assessment score.

Unreasonable course assessment and lack of timely feedback

The assessment and evaluation design of some courses is unreasonable. For example, students were asked to watch the recorded video or MOOCs in some courses. the learning attitude and effect of students were measured by the watching time of students. Some students increased the watching time without actually watching it to meet the requirements of teachers. According to the questionnaires, many courses increased the task before and after class to improve the learning effect. However, with the increase of homework and the large number of students, students could not get the feedback from the teacher in time. 33% of students complained that they did not receive the evaluation. As we know, if students' learning process cannot be effectively evaluated, the closed-loop ecology required by constructivism cannot be realized, which affects the teaching effect.

ONLINE TEACHING MODE STRATEGY BASED ON CONSTRUCTIVISM

Enrich platform functions through technology empowerment

The integrated platform with perfect functions is necessary for online teaching. With the development of big data technology, artificial intelligence and 5G technology, it is possible to develop an integrated platform with the functions of online teaching, classroom attendance checking, learning process tracking by recording watching video and reading material time, assignment release and submission, performance feedback data analysis of students' learning effect, group video discussion, etc. The integrated online platform builds a virtual classroom for teachers and students, which provides students with learning convenience and increases their learning experience. Teachers can provide personalized support and guidance for students by the help of learning process track and students' learning effect reports generated by the platform. At the same time, the platform can help teachers build and archive teaching resources and the students' material generated by teaching activities Furthermore, the platform provides teaching quality monitoring and daily teaching organization management for the department of educational administration.

Improve teachers' teaching ability through training

Although many teachers have rich professional knowledge, they are lacking scientific teaching methods and the skills for using information-based teaching. (Xue & Guo, 2020). Teachers should strengthen self-learning in their own teaching ability. Colleges should provide teachers with relevant knowledge and skills training and carry out online teaching training through teaching method lectures, observation of famous teachers' demonstration courses, teaching experience sharing, etc. Teachers should update their teaching ideas, master online teaching methods, and effectively improve their online teaching skills.

Create teaching situation

Constructivism holds that students need to learn new knowledge actively. Generally, they learn new knowledge on the basis of their acquired knowledge. The process of their own construction of the knowledge requires the participation of the situational factor. Therefore, in teaching design, teachers should attach the importance to analyzing and evaluating students' original knowledge and experience, and provide students with various learning resources and scaffolding to meet the needs of self-learning of students with different cognitive levels. Creating the teaching situation is one of the most important factors in Constructivism.

The real-life scenario is the best teaching situation. However, it is difficult to meet the learning needs of students due to the difficulty of cost, safety, organization management, etc. Virtual simulation experiment can create a good learning environment for students (Liu et al., 2020). Students can enter the virtual practice place by wearing wearable devices, experiencing relevant business operations concretely and personally, to improve practical ability and to deepen the meaning of construction of knowledge.

Reconstruct teaching content with OBE teaching concept

Online teaching should be based on the OBE (Outcomes-based Education) concept. Teachers organize teaching activities flexibly according to students' characteristics, course nature and implementation conditions, so as to realize the fundamental transformation from “teaching centered” to “learning centered”. Teaching content, teaching links, learning strategy, learning resources and learning evaluation are based on the learning objectives. Teachers refine all the teaching contents into individual knowledge point. Different teaching strategies are used for the different difficulty level. For the easy knowledge point, students can learn by themselves before class. On the contrary, the key and difficulty points will be taught and discussed fully in class, even the scaffolding needs to be provided by the teachers if necessary.

Design reasonable evaluation methods and give timely feedback

In the course evaluation, teachers not only need to evaluate the mastery of students' knowledge and skills, but also pay attention to the comprehensive evaluation of students' cognition, emotion, attitude and so on (Yu & Zhang, 2020). The evaluation is not limited to the simple memorization and reproduction of the knowledge learned in the classroom and textbooks, but more emphasis on the application of knowledge in different situations. The ultimate goal of knowledge learning is to solve problems in real life, so in the process of evaluation, teachers should also highlight the ability of students to solve practical problems. No matter what kind of evaluation methods, timely feedback is required to be given for their learning effect at each stage. With the support of information technology, real-time feedback of close answer questionS and some open-ended questionS have been realized. In the near future, more open-ended questions can be evaluated based on big data technology and artificial intelligent technology to improve the feedback time and reduce the teacher's workload.

Promote online and offline "double line" integration

With the effective control of the epidemic, teachers and students will return to the classroom for face-to-face teaching. However, after a round of online teaching during the epidemic period, teachers and students have realized the advantages of online teaching. In their opinion, online preview, online quiz and online Q&A are more effective than those of offline. Therefore, it is a tendency to study the integration mechanism of online and offline, and build a new normal of education and teaching by activating the existing resources, and carrying out blended teaching practice.

CONCLUSIONS

Although the online teaching mode is a new attempt for most university teachers, who encounter various problems in the process of implementation, the mode of thinking, the form of communication and the mode of course teaching of online education will have a far-reaching impact on the teaching of many courses. Big data, artificial intelligence, 5G and other information technologies bring more possibilities for the development of education. Under the guidance of constructivism theory, teachers should make full use of information technology to carry out student-centered classroom teaching and improve students' learning effect. It will be an important task to improve online teaching quality and build a teaching mode of integration and collaborative development of online and offline teaching in the future.

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IMPLEMENTING EDUSCRUM METHODOLOGY IN ONLINE PROJECT-BASED LEARNING

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ABSTRACT

Design activity is one of the most important components of the professional image of a modern engineer. This type of activity significantly increases the effectiveness of educational programs. The participation of students in the implementation of complex projects on real topics contributes to the rapid acquisition of professional competencies. The EduScrum methodology allows students to participate in real project team activities and effective interpersonal interaction. The most serious challenge of our time is the COVID-19 pandemic. Forced restrictions on personal contacts damage business processes. However, the correct process control mechanism ensures their stability. The functionality of the EduScrum methodology allows the project activities to continue. The efficiency of project activities in the field of IT projects has even increased in some cases. The restrictions helped to optimize the project activities of the team. It was revealed that the high efficiency of the CDIO methodology implementation is ensured by the involvement of students in the implementation of socially-oriented IT projects. The impact of project activities on increasing motivation and academic performance was assessed.

KEYWORDS

Team project activities, Distant learning, EduScrum, Standards: 3,5,7.

INTRODUCTION

Engineering students need the competencies of practical project activities in a team. One way to do this is through the CDIO initiative. The success of the initiative is largely based on the use of Project-Based Learning (PBL) in the educational process (Crawley E. F., Malmqvist J., Östlund S., Brodeur D. R., & Edström K., 2014).

In accordance with standards 3, 5, 7 of the CDIO initiative, Surgut State University implements project-based learning. The main focus is on the project activities of students in teams.

Due to the limitations of the COVID-19 pandemic, most students are now studying online. Face-to-face interaction is minimized. However, team project activities can be effectively carried out in accordance with the EduScrum methodology. This methodology can be successfully adapted for organizing project activities online. It can be most effectively applied in IT projects. The Conceive and Design stages can be efficiently implemented online. There are many free and paid services for organizing video conferencing and teamwork. In student IT projects, most often, the implementation of the Implement and Operate stages does not require complex implementation at the hardware level. Often, the functionality provided by existing IT services and platforms is sufficient.

ARRANGE OF PROJECT ACTIVITIES ONLINE

In practice, it has been proven that the intensive use of project activities throughout the entire period of study at the university contributes to the effectiveness of the educational program (Standards 3, 5, 7). Education with a systematic, intensive use of project activities ensures the formation of fundamental engineering competencies of students (Grishmanovskiy P., Grishmanovskaya O. & Zapevalov A., 2020), (Rebrin O, Sholina I., & Berestova S., 2014). The experience of colleagues proves that the use of project activities motivates students to a deeper study of the professional field (Siong, G., & Thow, V. S., 2017), (Nguyen-Xuan, H., & Sato, K., 2018).

At Surgut State University, the project activities of students enrolled in the "Software Engineering" program are organized according to the EduScrum methodology (Zapevalov A., Kuzin D. & Grishmanovskiy P., 2020). EduScrum methodology is detailed in publications (Delhij, A., van Solingen, R., & Wijnands, W., 2015), (Wijnands W., & Stolze A., 2019). This methodology is a further development of Scrum (Sutherland, 2014), adapted for the education system. There is a successful experience of using Scrum and EduScrum in a number of universities - members of the CDIO initiative. (Ferreira, E. P, & Martins, A., 2016), (Paul, R., & Behjat, L., 2019).

The eduScrum team consists of a curator who is assigned the Product Owner role and student teams of 3 to 5 people. Typically, the role of Product Owner is assigned to a teacher. In each team, one of the students is assigned the role of EduScrum Master. The student performing this role is not a leader, he optimizes the work of the team and is engaged in inter-team interaction. The project is divided into several stages called Sprints. In each sprint, one or more project tasks are solved. Sprints can last from 1 week to 1.5 months.

In 2020, the use of the EduScrum methodology has been expanded. Due to the covid-19 quarantine, students studied online. The functionality of the EduScrum methodology has ensured the efficiency of project activities using IT.

Information support for online project-based learning

To manage the team project activities of students at the Surgut University, a specialized automated information system “AIS Student” has been implemented (http://student.surgu.ru). The home page of the system is shown in Figure 1.

The system helps to create interdisciplinary project teams. It works as an exchange of available vacancies in projects for students, and helps the curator (Product Owner) find participants with the required skills. Any registered user can apply for participation in the project with the chosen role and become a member of the project team.

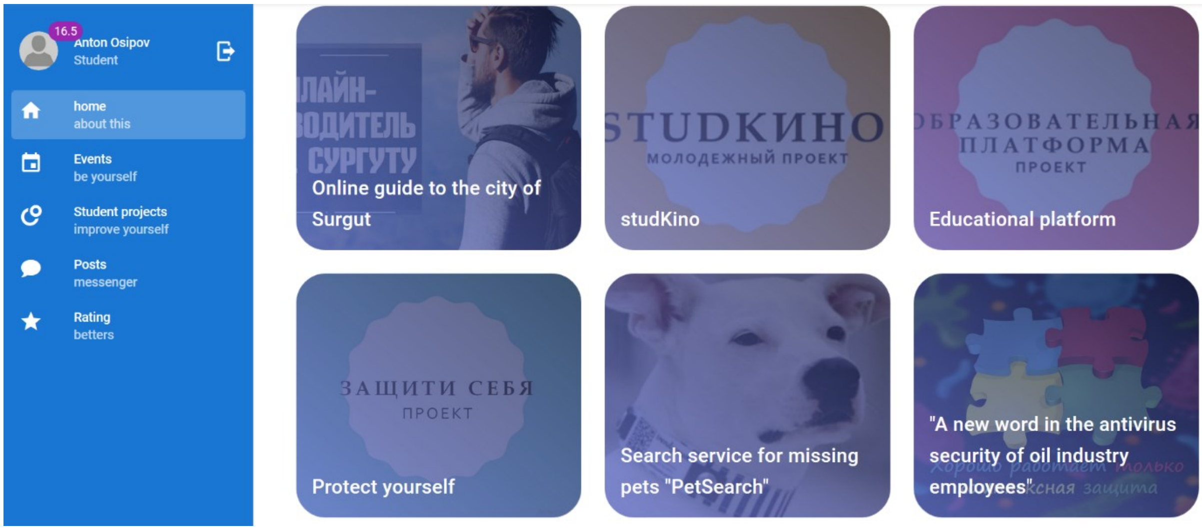

Figure 1. The home page of the specialized information system “AIS Student” (http://student.surgu.ru)

Product Owner creates a project in the system, defines its theme, goals, required resources and vacancies for participants. All information about the project is displayed on the project card. Sample project cards are shown in Figure 2.

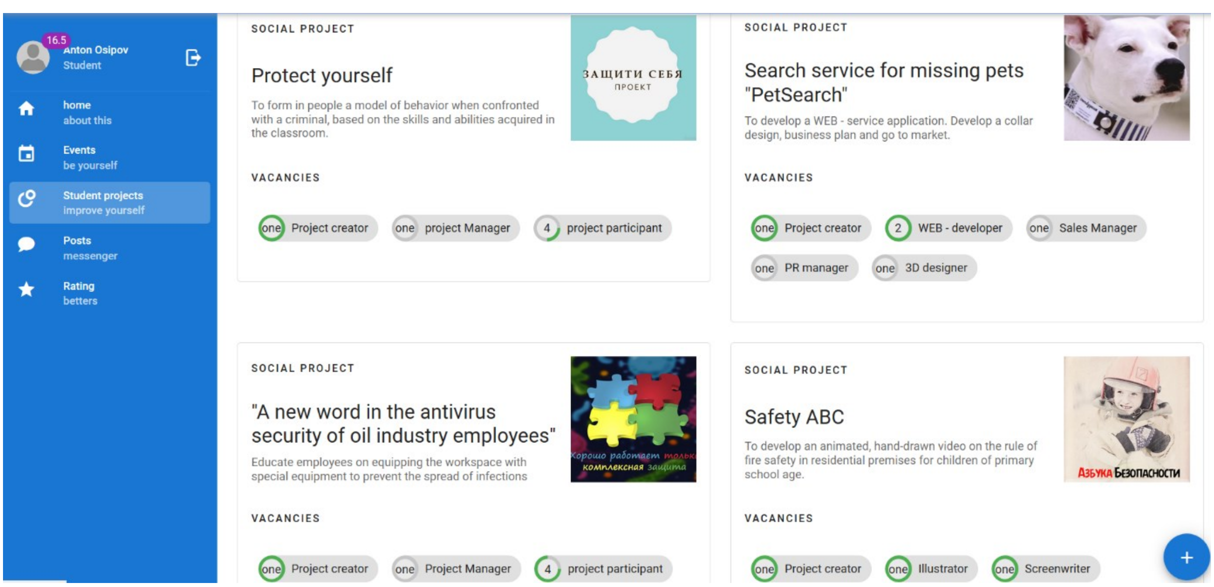

Figure 2. Cards of projects in information system “AIS Student”

Stage "Conceive"

This stage lasts 2-4 weeks. At the conceive stage of project a team is formed. Typically, students sign up for teams on their own, but the Product Owner can send personal invitations to potential team members. Project cards contain only minimal information. Detailed information on team members, project goals and objectives, planned results and required resources is contained on the corresponding project page. An example of a project page is shown in Figure 3.

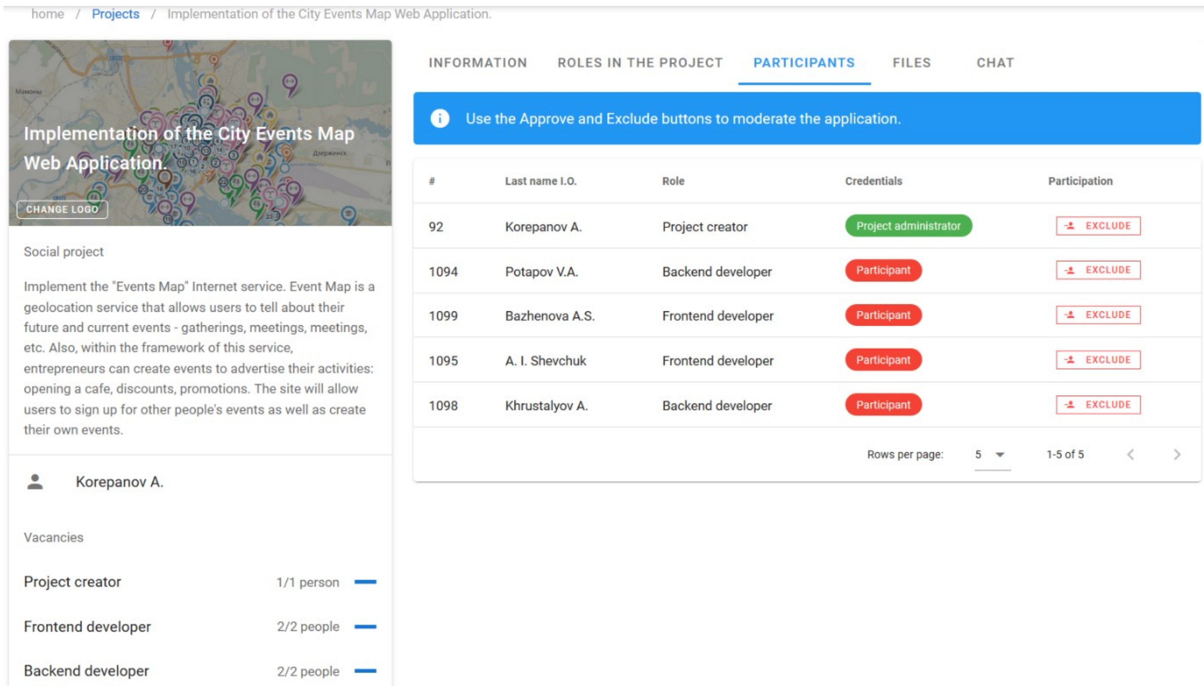

Figure 3. Project page example in information system “AIS Student”

At the beginning of the project, at the Conceive stage, students, together with the Product Owner, choose a platform for video conferencing. Then the tasks and timing of the project are determined. A Scrum Board is created, a Scrum Master is elected, a calendar of meetings is assigned. The Project Passport is created as the main project document.

Online participation in project activities forces contractors to more thoroughly document all stages of the project than before. It reduces the risk of making or uncoordinated decisions.

Stage "Design"

At the Design stage, students explore ways to solve the assigned tasks. Changes in interaction procedures are also noted here. Sprints have become more discrete, shorter and more intense. In some teams, the Scrum Master held operational meetings twice a day - morning and evening. Meetings with the Product Owner are held 1 - 2 times a week (Figure 4). The localization of tasks within sprints has increased. This made it possible to increase the speed of project implementation.

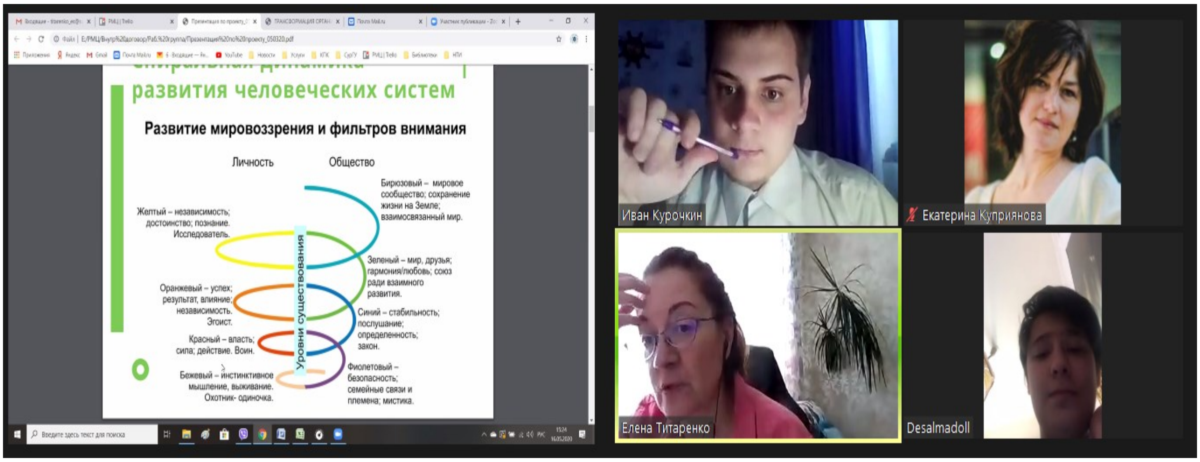

Figure 4. Online meeting of team members

Weekly meetings between one Product Owner and a Scrum Master from different competing teams contribute to a more competitive product. At the meetings, the team leaders present the results of the current stage, talk about project solutions, successes and difficulties.

The analysis of competitor teams allows the Scrum Master to evaluate his team and make adjustments to its work. On the other hand, the team may see some solution or idea that will improve their project. All this has a positive effect on the results of the project.

Stage "Implement"

This sprint implements the concepts developed at the previous stage. The stage lasts 6 to 8 weeks. Software components are being developed. At weekly team meetings, the performance of the work performed is analyzed. The implemented functionality, convenience and friendliness of the interface are evaluated. System components such as client and server are tested together. Much attention is paid to the implementation of human-machine interaction. The result of this sprint is a fully functional prototype of the system.

The EduScrum methodology is most successfully applied in online IT projects. In the spring semester of the 2019/20 academic year, a number of projects have already been completed and implemented. Currently, several competing teams are carrying out a project to create a 3D-model of the university campus in Minecraft. Examples of 3D models of the university building are shown in Figure 5.

A 3D modeling project for the university campus is currently under construction. The teams have already modeled some of the university buildings and are continuing to model other campus buildings.

Figure 5. 3D models of the university building in the Minecraft environment

Stage "Operate"

This is the shortest of all stages, lasting 1–2 weeks. At the Operate stage, the results of the project are presented and evaluated publicly. To increase the effectiveness of personal and interpersonal communication skills, a competition of student teams' projects is held. During the competition, project teams present their projects to the jury, receive expert opinions and reviews. The jury is composed of PhDs and industry representatives. According to the competition, a rating of teams and an individual ranking of students are built (Figure 6). The rating is published on the AIS “Student” page and is publicly available. The figure shows a small piece of data arranged from top to bottom. At the top of the rating, many students have the same rating value, due to the large number of participants in project activities and the unification of the content of the corresponding academic disciplines.

Figure 6. Ranking of students and project teams in information system “AIS Student” in 2020

A significant advantage of socially oriented IT projects is the ability to test them in operation. At the operational stage, the project is at least tested. The project team receives feedback from project users. Based on the feedback received, adjustments are made to the project. In some cases, it is necessary to rethink design solutions or concepts. Maintaining and modernizing the IT system can be a challenge for the next project.

CONCLUSIONS

This paper presents the practical results of adapting the EduScrum methodology to online learning. The implementation of EduScrum has ensured success in project-based learning. Distance learning experience has shown that the effectiveness of online project activities does not decrease, and sometimes even increases. This conclusion was made based on the results of comparing the assessments of students studying full-time and students studying online. In many disciplines there is a slight decline in student performance, but in project-oriented disciplines, academic performance persists or increases.

EduScrum has proven to be more effective online for IT projects compared to other types of projects. This is due to the high importance of information technology in organizational and communication procedures for online learning. The limitation of personal contacts due to the pandemic has contributed to the modernization and optimization of project activities.

Successful experience of using the EduScrum methodology online together with AIS "Student" contributes to the expansion of the scope of projects.

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IMPACT ANALYSIS OF ACADEMIC REFORMS FOR CDIO IMPLEMENTATION: CASE STUDY

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ABSTRACT

Thiagarajar College of Engineering (TCE), Madurai, India is a member of Worldwide CDIO Initiative and has been practicing CDIO based curriculum from the academic year 2018-19. The self-assessment of CDIO standards has been carried out meticulously by the CDIO group members of the institute in the academic year 2017-18 and a detailed action plan has been evolved for enhancing CDIO skills. As a first step, the curriculum of undergraduate programmes has been revamped to promote Design–implement Experience and Integrated Learning Experience. New courses like Engineering Exploration, Lateral Thinking, Design Thinking, Project Management, System Thinking and Capstone Projects are offered to promote technical, personal and interpersonal skills. As a second step, to enhance Faculty Teaching Competence, exclusive in-house training programmes on CDIO skills and pedagogical training programmes in association with international experts have been successfully conducted. Successful implementation of Engineering Projects in Community Services (EPICS) Program at TCE has resulted in 164 prototypes to address location-specific community problems. A new framework has been developed to introduce a wide variety of assessment methods to assess technical, personal skills and interpersonal skills of learners. An in-house customized web application for effective assessment of learning outcomes has been developed. This article presents the impact analysis of the academic reforms made in the curriculum, content delivery and assessment at TCE in enhancing the rating scale for the CDIO standards namely Design - implement experiences, Integrated Learning Experiences, Active Learning, Enhancement of Faculty Teaching competence and Learning Assessment. It can be observed that there is great positive impact of these academic reforms not only in improving the ratings of CDIO standards but also in getting national level accreditation and in improving the ranking of the Institute.

KEYWORDS

CDIO implementation, Active Learning, Integrated Learning Experience, Faculty Teaching Competence, CDIO based Curriculum Design, Standards: 5, 7, 8, 10, 11

INTRODUCTION

During the 60th year of establishment of our institution, the Internal Quality Assurance Committee of TCE revisited the academic, research, industry interface and extension activities so that the institution can be moved to the next level. It is observed that, in the past two decades, 90% of the graduates are getting employment in software industries. With the emerging opportunities in core engineering disciplines, students are not able to meet the stringent requirements of core engineering industries such as hands on skills and system approach. Though we have been following outcome based education framework, the hands-on practices, system design thinking leading to product development approach and interpersonal skills have not been much emphasized in the curriculum. Further, many of the students who get placed in software industries also want to switch over to core engineering jobs. By becoming the member of the CDIO Initiative, we hope to adopt and share the best practices and standards from other CDIO member institutions. TCE membership in the CDIO Initiative has enhanced the opportunity for faculty exchange and global student contest. We are convinced that, by adopting the CDIO framework, we could meet the global requirements of the professional engineer. This paper presents the various activities carried out in TCE for exclusively for bringing improvement in the CDIO Standards 5, 7, 8, 10 and 11 respectively

RESEARCH QUESTIONS

The motivation of this experimental study is supported by the following Research Questions (RQ):

RQ1: What is the impact of the curriculum revamp and newly introduced CDIO based courses in enhancing design implement experiences and integrated learning experiences?

RQ2: What is the impact of exclusive training programs on pedagogy and CDIO implementation in promoting active learning, faculty teaching competence and learning assessment?

IMPACT ANALYSIS OF ACADEMIC REFORMS ON CDIO STANDARDS

During the initial phase of incorporating CDIO as the education framework at TCE in the academic year 2017-18, an exclusive working group for promoting CDIO initiatives at TCE has been constituted with representatives from all the departments. The self-assessment of CDIO standards has been carried out meticulously by the CDIO group. A detailed action plan has been evolved for improving the quality of the academic process with the prime focus on enhancing CDIO skills. This section explains various reforms and initiatives in the context of CDIO implementation and its subsequent effects in the improvement of rating in CDIO standards.

IMPACTON DESIGN IMPLEMENT EXPERIENCE

In the academic year 2018-19, curriculum of all the undergraduate programmes in TCE have been revamped exclusively to promote design implement experience. Unique features of the CDIO based curriculum at TCE has been presented in Figure 1. New courses pertaining to CDIO standards have been introduced to create Design- Implement experience namely, Engineering Exploration, Lateral thinking, Design thinking, System thinking, Engineering Design project and capstone project contributing 20% of the total credits.

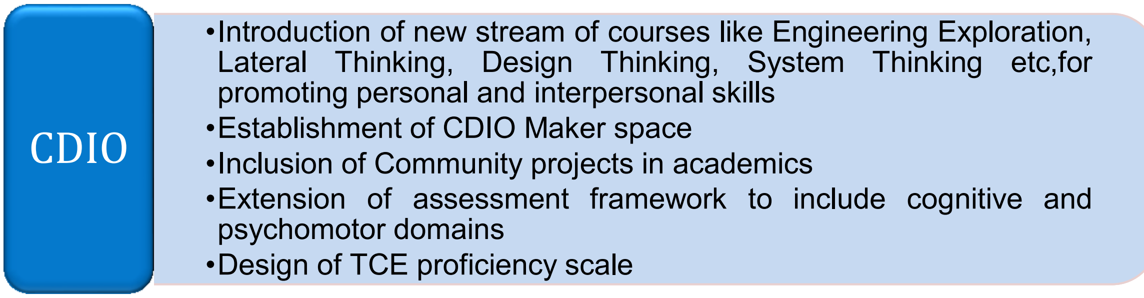

Figure 1. Features of CDIO curriculum @ TCE

Table 1. Uniqueness of CDIO Curriculum @TCE

Total Number of New courses offered	733
Total Number of New Core Courses offered	476
Total Number of New Elective Courses offered	257
Total Number of Industry Supported Courses	113
New Audit Courses for UG Engineering Students	Environmental Science Constitution of India Essence of Indian Knowledge
New Audit Courses for PG Engineering Students	Professional Authoring Value Education

Faculty members have been trained in these areas and have been assigned as faculty guides to train the students. Also, 205 faculty members have been trained in CDIO based curriculum design during May to June 2020 and the feedback given by the faculty members are illustrated in Figure 2. To promote design thinking (Donne, 2018; Rodriguez, 2019), a special program, Engineering Projects in Community Service (EPICS) has been initialized to understand the lifestyle of the local community partners and to identify their potential problems. Among 43 projects carried out during 2019, 5 projects have been successfully made their way with the prototypes. The projects include Agricultural support systems, Blended learning application for village students and Assistive technologies for autism affected children. The work has been presented in the paper (Thiruvengadam et al., 2020b) as an outcome of Design-implement Experiences in the host institution. The major milestones in the EPICS project at TCE are depicted in Figure 3. Photographs of the exhibits of the outcomes of EPICS and review of EPICS project are presented in Figure 4. Significant outcomes 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. Many of our students have extended their projects of design thinking and exhibited their implementations in national level contest like Smart India Hackathon and IUCEE-EPICS Design contest and received good recognition and rewards.The above mentioned initiatives have taken the CDIO self assessment for the standard Design Implement Experience from Level 1 to Level 4 as shown in Figure 5.

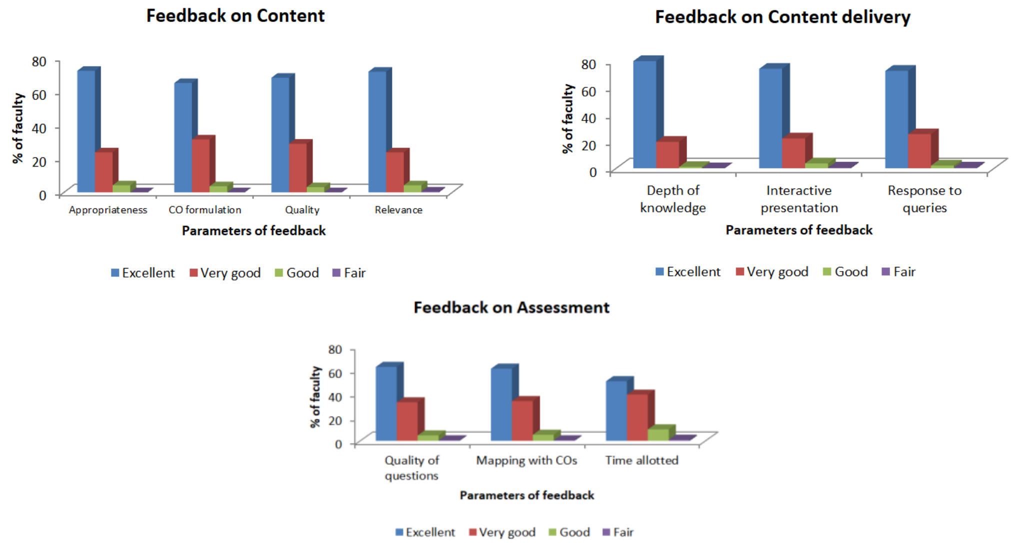

Figure 2. Faculty Feedback on CDIO curriculum design workshops

Figure 3. Milestones in EPICS Project

Figure 4. Exhibits and Review of outcomes of Design Thinking

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

Figure 5. Progress in Design Implement Experience

IMPACT ON INTEGRATED LEARNING EXPERIENCE

According to CDIO standard 7, Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, product, process, system, and service building skills. Acquisition of disciplinary knowledge shall be observed from the academic performance of the students whereas personal and interpersonal skills are connected with their communication skills and teamwork skills. After getting a detailed feedback from the student after the experience, analysis of the feedback is made. The design-implement experience in EPICS projects are related to integrated learning experience. As the major components of integrated learning experience are Knowledge acquisition, personal & interpersonal skills and system building skills, the feedback of students are taken to account to find whether the efforts are bringing positive results. The feedback is collected after the learning experience with a likert scale of 1-4 in the learning experience gained by the students with the given parameters as in Table 2. 520 students in the fourth semester in the academic year of 2019-2020 participated in the survey and presented their views. The responses of the students have been presented in Figure 6. It can be inferred that majority of the students have given top two ratings thereby demonstrating high satisfaction index.

Table 2. Feedback parameters after the learning experience

Parameters of Integrated Learning Experience	**Sub parameters considered for getting feedback**
System building skills	1.1 Identification of societal problem
	1.2 Formulation or modelling the problem
	1.3 Literature review
	1.4 Prototype development
Knowledge acquisition through development process	2.1 Specification development process
	2.2 Functional decomposition
	2.3 Final Poster presentation
Inter and intra personal skills	3.1 Communication skills
	3.2 Teamwork skills

Maker space in TCE has been established in the academic year 2018-19 with an objective to enable the students to innovate, design, build and develop prototypes of their ideas that have been conceived in engineering, science and interdisciplinary domains. Figure 7 presents the facilities of CDIO maker space at TCE. From these observations, it is evident that there is a documented evidence that there is an impact of integrated learning experiences across the curriculum. Further, it is also important to note that two of the student projects are selected as the best project posters in the event of the 7th International Conference on Transformations in Engineering Education (ICTIEEE, 2020). Hence, these reforms take the CDIO self assessment for the standard Integrated Learning experience from Level 2 to Level 4 as shown in Figure 8.

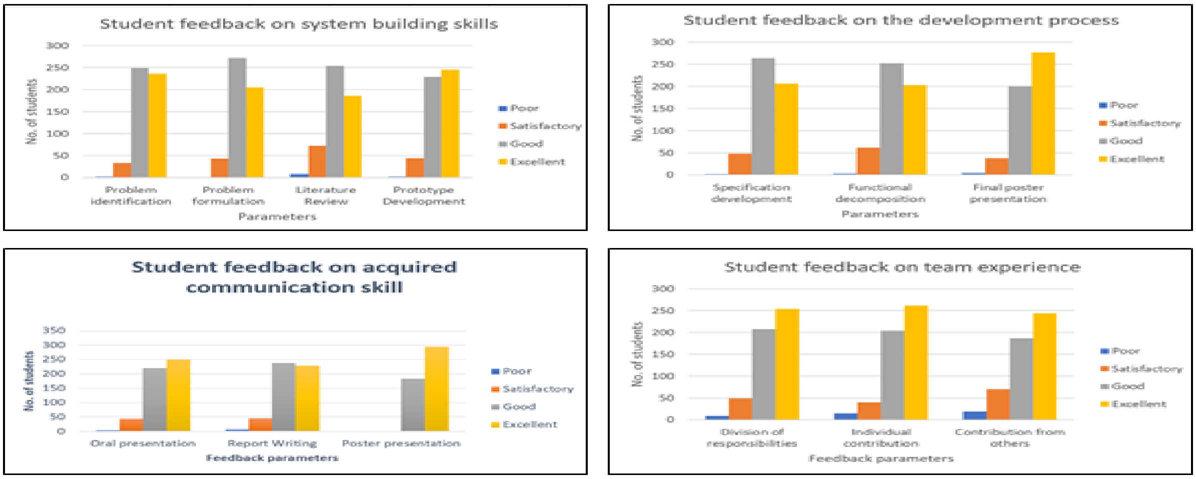

Figure 6. Learners' feedback on system building, team work and communication skills

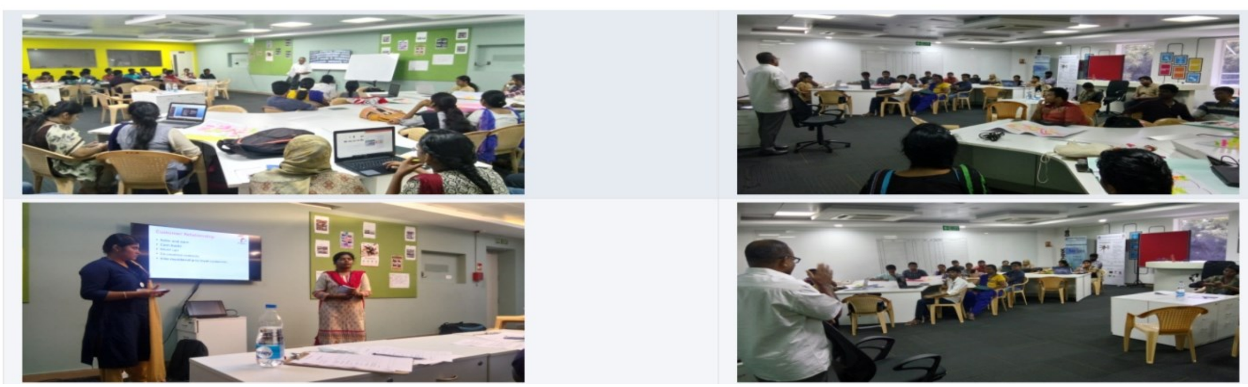

Figure 7. CDIO Makerspace @TCE

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

Figure 8.Progress in integrated learning experience

ACTIVE LEARNING

Active learning methods aim at improving the engagement of learners by involving them in problem solving activities which involve critical thinking. During the self-assessment of CDIO standards in 2017, it has been inferred that active learning methods are implemented in many of the undergraduate courses. However, no impact analysis of active learning strategies on the improvement of learning outcomes has been made and is not documented. Only a few faculty members were interested in adopting modern pedagogical practices and ICT tools in their teaching. The self-assessment for the CDIO standard on active learning is “2” in the academic year 2017-18.In order to improve the rating, a series of capacity building workshops and training programmes on Pedagogy and ICT tools for education were planned for the academic years 2018-19 and 2019-20 respectively. Around 20 faculty members have been certified in the International Engineering Educator Certification Program (IIEECP) offered by the Indo Universal Collaboration for Engineering Education (IUCEE). The program included training on the principles of learner-centered teaching, designing or redesigning a course and its elements, emphasizing learning outcomes, development of different teaching and active learning strategies, and designing formative and summative assessment tools and rubrics for outcomes assessment. The list of in-house faculty training programmes organized is presented in Table 3. Figure 9 presents the photographs of various training programmes conducted for promoting active learning.

Table 3. List of training programmes for TCE faculty

S.No	Date	Programme	Count of Participants
1.	May – Jun 2018	Development of CDIO based Undergraduate Engineering Curriculum	20
2.	Jun – Sep 2018	Two week workshop on Pedagogy for use of ICT in Education	20
3.	Oct – Dec 2018	Two week workshop on Pedagogy for Online and Blended Teaching-Learning Process	15
4.	Feb 2019	Programme Assessment – Self Evaluation as per CDIO Standard	20
5.	May - Jul 2020	CDIO Based Curriculum Design (three batches) 1. Batch 1:27-05-2020 to 02-06-2020 2. Batch 2: 15-07-2020 to 22-07-2020 3. Batch 3: 27-07-2020 to 31-07-2020	220
6.	4-5, August 2020	Developing learner-centric online courses: Resilient Teaching Approach	40

Figure 9. Faculty Training Programmes @ TCE

To enforce the implementation of active learning in all classrooms, a common template for instructional design has been developed and is presented in Figure 10 and a sample can be found in the link https://tinyurl.com/4azdy6p4.

Course Plan:

Module No.	Module Name	Cos	Duration (Hours)	Content Delivery Method	Resources / Tools required	Active learning strategy
	Course Outcome					

Figure 10. Template for Instructional Design

Wide usage of active learning has resulted in improved learning outcomes. Exclusive question banks have been developed to enhance higher order thinking skills of learners. Also, the experience of the learners has been recorded in course end surveys. Figure 11 represents the learner feedback on few sample courses.From these observations, it can be inferred that there is documented evidence on the impact of active learning methods on students learning. Hence, these reforms take the CDIO self-assessment for the standard on active learning from Level 2 to Level 4 as shown in Figure 12.

15. Use of black board and active learning methods

Options	Score	Count	Percentage
Excellent	1	23	46
Very good	0.75	17	34
Good	0.5	10	20
Poor	0.25	0	0

Python Programming

15. Use of black board and active learning methods

Options	Score	Count	Percentage
Excellent	1	26	40.63
Very good	0.75	25	39.06
Good	0.5	12	18.75
Poor	0.25	1	1.56

Information Security

15. Use of black board and active learning methods

Options	Score	Count	Percentage
Excellent	1	14	53.85
Very good	0.75	9	34.62
Good	0.5	1	3.85
Fair	0.25	2	7.69

Data Structures

15. Use of black board and active learning methods

Options	Score	Count	Percentage
Excellent	1	28	41.18
Very good	0.75	21	30.88
Good	0.5	18	26.47
Fair	0.25	1	1.47

Computer Networks

Figure 11. Learners' feedback on Active Learning

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

Figure 12. Progress in Active Learning

IMPACT ON FACULTY TEACHING COMPETENCE

The training programmes at regular intervals and constant support and encouragement by the management and superiors, for the use of active and collaborative learning strategies has resulted in significant improvement in the faculty teaching competence. TCE, with its strong passion for research, supports research in Engineering Education also. The faculty of TCE has participated in various Engineering Education Research (EER) courses offered by IUCEE. The impact of adopting active learning strategies has been analyzed and published in various educational conferences and journals. The increase in the publications in Engineering education has been increased to 31 for the last three academic years. Having gained expertise on the use of various pedagogical approaches and ICT Tools for education, faculty members have organized exclusive training programmes for the benefit of neighboring and partnering colleges. Sharing of best practices and knowledge sharing with other colleges has led to collective growth in the society. The list of training programmes organized by the faculty members of TCE is presented in Table 4.

The faculty members of TCE are presently involved in creating 39 online courses for the benefit of the student community. The courses are selectively designed to improved transition rate, to enable skill development and to promote interdisciplinary research. Based on these observations, it can be inferred that the collective faculty is competent in teaching, learning and in assessment methods. Figure 13 represents the progress in the CDIO standard on Active Learning from level 2 to level 4.

Table 4. List of training programmes by TCE faculty

S.No	Event	Beneficiary
1.	TEQIP Twinning programme on Effective implementation of Outcome Based Education, Mar 2018	Harcourt Butler Technical University, Kanpur
2.	ICT Tools for Effective Teaching, Jan 2019	Faculty from colleges in Tamil Nadu
3.	AICTE QIP sponsored Two week STTP on Effective implementation of Outcome Based Education, Mar 2019	Faculty from colleges in India
4.	AICTE QIP sponsored One week STTP on Pedagogical innovations and Research Directions in STEM Education, Feb 2019	Faculty from colleges in India
5.	Aligning Curriculum Design and Development, content delivery and assessment, Sep 2019	GMR Institute of Technology, Vishakapatnam
6.	Sharing of CDIO practices with the academic community: Best practices in the context of TCE are shared to the academic community through IUCEE Webinar Series – 4 Lectures	IUCEE consortium Members
7.	Best Practices in TCE Academic Process	Jain University, Bengaluru
8.	Typical Curriculum in Engineering and Technology Organized by CII Southern Region, at Sathyabama University, Chennai and at Mysore	Faculty from colleges in India
9.	Unified Academic Processes For Higher Education by Octoze Technologies Pvt.Ltd, Chennai	Senior Faculty Members In India

Scale	Criteria
5	Faculty competence in teaching, learning and assessment methods is regularly evaluated and updated where appropriate.
4	There is evidence that the collective faculty is competent in teaching, learning and assessment methods.
3	Faculty members participate in faculty developmet in teaching, learning and assessment methods.
2	There is a systematic plan of faculty development in teaching, learning and assessment methods.
1	A benchmarking study and needs analysis of faculty teaching competence has been conducted.
0	There are no programs or practices to enhance faculty teaching competence.

Figure 13. Progress in Faculty Teaching Competence

LEARNING ASSESSMENT

The implementation of competency based education in 2008, followed by outcome based education in 2014 and the inclusion of CDIO in 2018 has helped us to update the course contents and improve content delivery significantly. To take it to the next level the academic team felts the need to revise assessment pattern that can given an opportunity for learners to demonstrate or display their depth of learning. Hence, interim assessment is designed that requires students to exhibit their knowledge and skills at various levels. Interim assessment is considered as a part of continuous assessment test and is composed of three categories:

- Category 1 - Knowledge/ concept level (25% weightage) will help to evaluate the conceptual knowledge of the students which can be carried out using quiz, poster presentation, worksheets etc.
- Category II - Presentation/communication skill (25% Weightage)is designed to enable students to demonstrate their presentation skills through seminars, comprehensive viva, video lectures etc.
- Category III - Professional skill – (50% Weightage) is again another activity based assessment to assess the higher cognitive levels. Here students will be evaluated using mini project, Concept test at HOTS, Journal reviews, case analysis etc.

The developed Interim assessment is student centric and helps to engage the students effectively during the course. It helps to them to think and act beyond text books/classroom and students were able to perform well in higher cognitive levels.

An in-house web application TCENeT-Gen3 has been developed to measure course outcomes and program outcomes effectively. The tool is capable of accommodating a wide variety of assessment strategies and measures the intended learning outcomes. A snapshot of the functionalities of TCENet is represented in Figure 14. The assessment of learning outcomes in TCENet is represented in Figure 15.

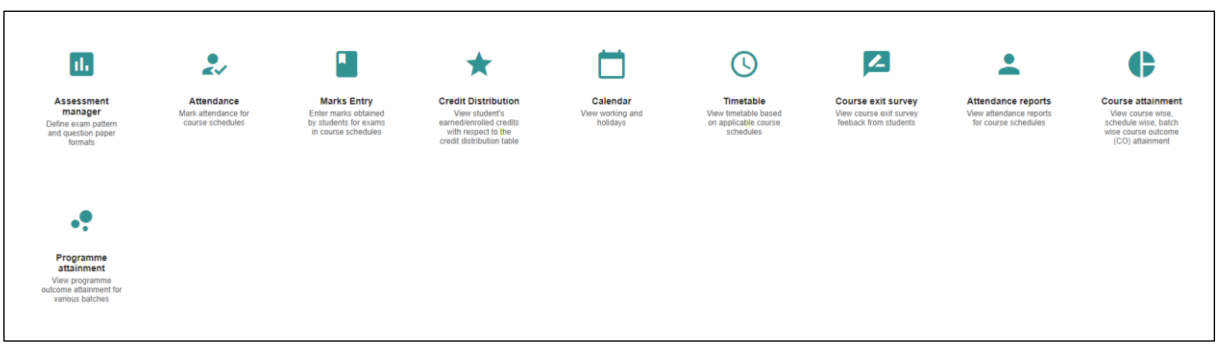

Figure 14. TCENet – Gen 3 Functionalities

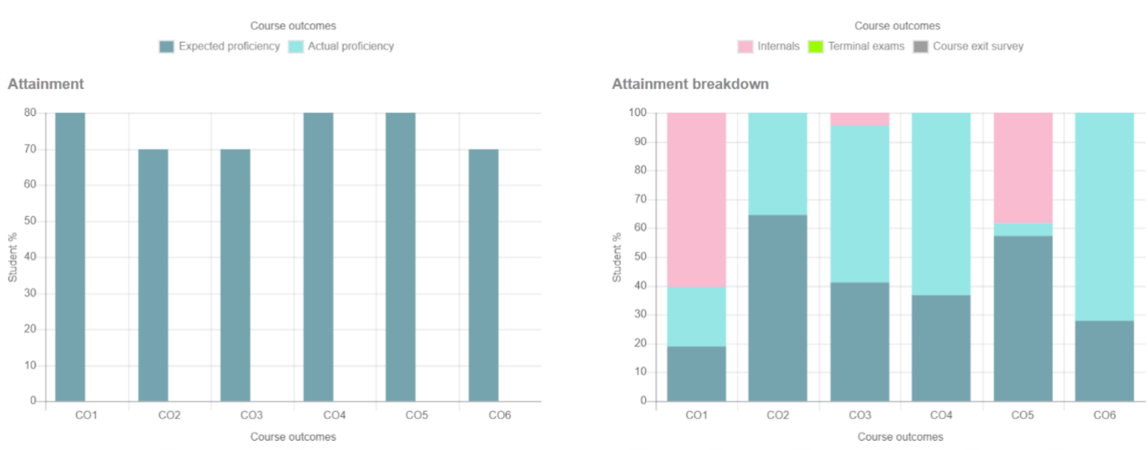

Figure 15. Assessment of Course Outcomes

An internal academic audit is also conducted every semester to measures the effectiveness of teaching learning and provide feedback and guidance for continuous improvement. Based on the above evidence, it can be inferred that there is progress in the CDIO standard on Learning outcomes and is presented in Figure 16.

Scale	Criteria
5	Evaluation groups regularly review the use of learning assessment method and make recommendations for continuous improvement
4	Learning assessment methods are used effectively in courses across the curriculum.
3	Learning assessment methods are implemented across the curriculum
2	There is a plan to incorporate learning methods across the curriculum
1	The need for the improvement of learning assessment methods is recognized and benchmarking of their current use is in progress.
0	Learning assessment methods are inadequate or appropriate.

Figure 16. Progress in Learning Assessment

CONCLUSION

The various refinements in the academic process of TCE has brought many laurels to the institute.Various parameters such as quality of projects, placement records, students' participation in national/international competitions and Hackathons, publications in conferences/journals, course exit surveys were used as evidences for assessing the impact of the academic reforms at TCE. National Board of Accreditation (NBA), Government of India recognized TCE as a nodal centre for conducting training programme on Outcome Based Education and Accreditation for faculty members in Engineering Institutions and Universities. TCE has become a member in a Worldwide CDIO initiative in April 2019. TCE has also been recognized by Indian Institute of Technology, Madras (IITM) as "Best Partnering Institute" for active participation in Quality Enhancement in Engineering Education (QEEE) programmes. The institute has also received special appreciation from IITB for "Best Contribution to Learning Repository". Faculty members have received awards under the category of Institutional leadership and leadership in Community Project Based Learning. Students have won prizes in Smart India Hackathons and in contests organized by higher learning institutions. Seven faculty members have received International Engineering Educator Awards (Ing.Paed.IGIP) from International Society for Engineering Pedagogy, Austria. The academics team presently focuses on developing online value-added courses to enhance graduate outcomes and provide improved interdisciplinary learning opportunities for the students of TCE and other institutions and establishing technology-based learning environment for enhancing graduate outcomes of 21st-century learners.Journey of TCE Academic Process continues with its motto "Duty is life" and its principle "Quality and ethics matter"

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ADAPTIVE AND FLEXIBLE ONLINE LEARNING DURING COVID-19 LOCKDOWN

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ABSTRACT

The COVID-19 pandemic has adversely disrupted higher education. During March-May 2020, universities had to move from physical campuses to online globally to curtail the spread of the virus among students and staff which has restricted and prevented hands-on learning on campus. At Canterbury Christ Church University (CCCU), we have identified several challenges of online teaching and learning from observations and conversations with students: for challenges, students struggled as they had no face-to-face interaction with teaching and technical staff, no access to hardware equipment nor the campus library. Additionally, they had increased mental stress, digital poverty, reduced social contact with university life and experienced self-isolation. Opportunities on the other hand were identified as flexibility to study in a comfortable environment, better pace and time, cost-saving, access to more online resources as a substitute, new simulation tools for equipment. To incorporate the opportunities of online learning, we have implemented a multi-faceted approach to mitigate the impact of challenges of COVID-19 on the learning, teaching and assessment such as adaptable online live teaching (lecture and practical) session for synchronous learning and recordings of the live sessions, provision of pre-recorded sessions for asynchronous learning and online assessment formation, Virtual practical sessions to make them acquainted with software tools, Virtual CDIO (Conceive-Design-Implement-Operate) project sessions so that students could utilize the benefits of the CDIO framework and enhance their critical thinking to find an innovative solution while emphasizing team efforts and hands-on skill, a virtual engineering cafe for supporting students psychologically during the pandemic. Therefore, students could avail the benefit of flexible online learning, reduce isolation and increase accessibility to the learning, the teaching materials and the resources as per their pace, place and mode. In this paper, we have emphasized the above teaching strategies to develop adaptive and flexible online learning method.

KEYWORDS

Flexible online learning, online CDIO, professional skills, digital poverty, Higher Education, Standards: 6

INTRODUCTION

During the first wave of COVID-19, the education sector encountered many difficulties (UNESCO, 2020) because the majority of universities have had to close their physical campuses worldwide. Following the UK government lockdown guidelines, all higher education institutions in the UK were closed from approximately March to August. The move to off-campus learning restricted and prevented conventional face-to-face learning on campus; therefore, students are unable to engage in practical session such as hands-on training. Around the world, academics responded rapidly, shifting programmes to online learning and increasing the development of online pedagogy learning (Huang et al., 2020). Online learning/e-learning is not a new approach and started in 1989. Nevertheless, the online educational programme is getting popular among people with part-time jobs and caring responsibility because it appears to be the only option for them to change their career/progression. Despite its prominence in web-platform, online learning has a major drawback such as a sense of connection as students feel detached from others and cannot share their experience.

In the UK, for engineering students, hands-on skills are identified as one of the important learning outcomes in most of the modules and it must be developed within the higher education curricula by the UK engineering council and accreditation bodies, (Engineering Council, 2014): universities must fulfil these required activities. To continue to support student learning and to fulfil the requirements of PSRB (Professional, Statutory and Regulatory Bodies), most universities, including Canterbury Christ Church University (CCCU), have switched to online teaching and learning platform during COVID-19 (Dhawan, 2020), and rapidly developed on-line practical learning (Bangert et al., 2020). There are several challenges and opportunities for online teaching and learning method (Adedoyin and Soykan, 2020). A review on online learning reflects the socio-emotional aspects of students (Delahunty et al., 2014). It shows that social interaction improves the knowledge-sharing capacity of students and encouraged them to build their own identity. Because of 'virtualness', students will lack social interaction and a sense of community. After conducting a qualitative study on university students, Gabriel et al., 2020 raised some positive sides of online learning. Although students expressed their feelings about missing social contacts with friends and lecturers, they observed some elements of e-learning is effective for the future because of time, flexibility and engagement. A multi-institutional research study (Carter et al., 2014) shows four important components of e-learning: human connection, IT support, design, and institutional infrastructure. There are few challenges of e-learning for both students and tutors such as insufficient technical support and training, inadequate instructional design support, lack of institutional support in educational sectors. To overcome these issues, adequate technical infrastructure should be built by keeping student learning experience at the centre and technological need in e-learning should be separated from administrative functions. After reviewing the challenges and opportunities of online learning, we have accumulated a few of those issues (shown below).

At CCCU, one of the taught modules (delivered though online) was a programming module entitled 'Fundamentals of Computer Programming' for foundation year mechanical engineering students. In this module, we undertook several teaching strategies and considered it as a case study to improve the learning experience of students. As a part of the module learning outcomes, students should critically analyse how system interfaces to microprocessor/microcontroller and software programming, communicate and control peripheral components of an embedded system. Along with module-specific learning outcome, the course was supposed to incorporate professional skills (hands-on skill, teamwork, critical thinking, project writing skill), providing mental support while adhering to COVID-19 regulations. To achieve these objectives, the following learning and teaching methods were adopted to support the students during the lockdown such as flexible online teaching, virtual practical session, virtual CDIO project sessions and engineering cafe (Figure 1). The whole process was backed by the instructional infrastructure and IT support. The process of achieving technical/professional attributes is mapped with acquired activity (Figure 1). For example, flexible online teaching helped students to nurture their critical thinking through new type of knowledge, session on project writing skill while virtual CDIO project session enhanced their critical thinking, team effort, hand-on skill and project writing skill.

Challenges

- Poor engagement in study
- Hard to stay motivated during this crisis
- Too many online resources available and difficult to find the appropriate one
- Unable to access the library physically
- No face-to-face interaction with teaching and technical staff
- Some classes require software/ hardware that is only available at the University
- Mental stress
- No communication with peers/sense of isolation
- Difficult to organise a study group project / communicate and work as a group collaboratively
- Digital poverty
- Poor internet bandwidth
- Losing social contact with university life

Opportunities

- Flexibility to study in a comfortable environment
- Flexibility to work at a flexible pace and time
- Opportunity to participate in classes from anywhere
- No need to travel
- Cost-saving
- Have access to more online resources as a substitute; tutoring sessions moved online, and new simulation tool for equipment
- Increased opportunities for extended virtual peer interaction beyond class time
- Opportunity for 1 to 1 online session with the tutor
- Continue to provide education for students self-isolating or shielding

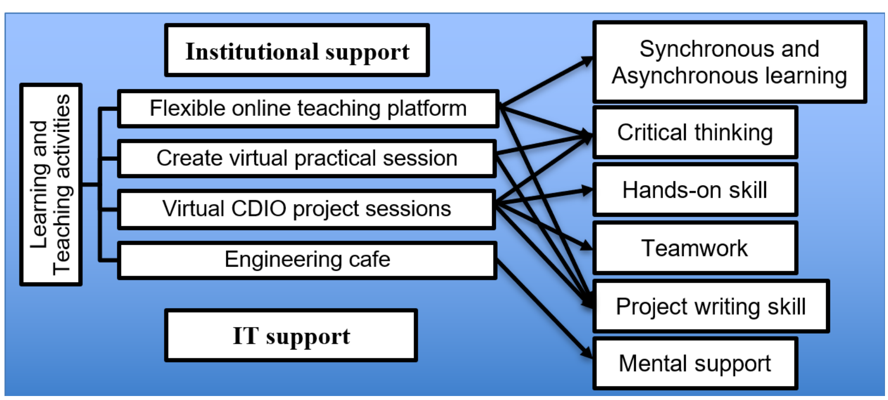

Figure 1. Teaching approaches to mitigate the limitations of online teaching and learning

FLEXIBLE ONLINE TEACHING PLATFORM

In CCCU, we have been provided with online learning and teaching software, Blackboard Collaborate Ultra that provides us with a user-friendly, flexible and interactive platform for both students and tutors, where we can easily record those sessions that could be followed and recapped by students later if necessary. Blackboard Collaborate Ultra is an effective, accessible, online teaching and learning tool that established a flexible learning environment (Zayapragassarazan, 2020) for tutees. It provides a platform where students can access the learning material in advance, can attend live academic session (lecture, practical, seminar, workshops and tutorial) as a form of synchronous learning (Finkelstein, 2006), can retrieve and download recorded sessions (asynchronous learning, Chen, Shang and Harris, 2006) and can attend online assessments. Submission of students' assessments and marking was easily done using this software. All lecture, practical and CDIO project sessions were delivered online using this software. Students could meet their peers virtually, pair up to create a group, interact with them and tutors from a socio-emotional perspective. Lectures on cutting edge technology, CDIO project helped students to develop innovative ideas around coding-based architecture while online training on project writing improved their report writing skill. Online teaching also facilitated socio-economic benefits to students and opened the door for other possibilities.

- Students could assess the learning material according to their convenience.
- This approach was useful for the students who were unable to travel to campus because of financial hardship, part-time job, or having to provide care for individuals affected by the COVID-19 pandemic, by providing flexible access to the teaching materials and recorded class sessions online.
- Another student demographic which was benefitted are mature students or students with sibling caring responsibilities who found balancing family/caring responsibilities and studies easier with flexible online teaching (lecture and practical) and recorded sessions. Due to the closure of schools, it was difficult for them to provide caring responsibilities at home when busy with the home-schooling of children rather than their study. The online teaching and learning platform and recorded academic sessions provided flexibility which made their lives easier whilst supporting family life.
- These recorded sessions were also considered beneficial to 'weaker' students and even enabled a few students to re-engage with the learning materials since students may need to recap certain material several times depending upon their comprehensive power. It also reduced the engagement time from tutors as students can revise from recorded material.
- Students who started new jobs in healthcare, retail, and social work, were unable to attend the scheduled taught session but were able to access it after their working hours.

CREATE VIRTUAL PRACTICAL SESSION

Since the university's research facility including labs had to be closed due to UK COVID-19 guidelines, there was no option available for students to continue the group-work based practical sessions on electronic circuits and hardware-based embedded system at the campus. In this programming module, the learning aspect of the practical session emphasized the fundamental concept and design of the Arduino board, the working principle of various sensors and its interfacing with Arduino. Students were also supposed to learn the relevant C/C++ programming for controlling it. Because of having online sessions, the students could not meet their peers to discuss group projects and missed personal guidance from module tutors, therefore it was not only difficult for them to fabricate and troubleshoot the Arduino circuit board but also to debug errors in the code. Although we could not facilitate physical lab sessions, we developed a similar kind of learning platform virtually (Babich and Mavrommatis, 2004) with Tinkercad software where the physical hardware-based electronic circuit had been replaced with a virtual board (Figure 2). Utilizing this tool, students could easily build Arduino circuits virtually with all its associated sensors, embed the programming code in the controller board to test and evaluate its function, and assess the compatibility of the programming in the virtual circuit board without making it. Separate sessions were delivered to students on how to write a project report describing the aims, methodology, design, development and testing results. Using the simulation-based software, students were not only able to attend the virtual practical session but also acquired the prerequisite knowledge for job-related skill.

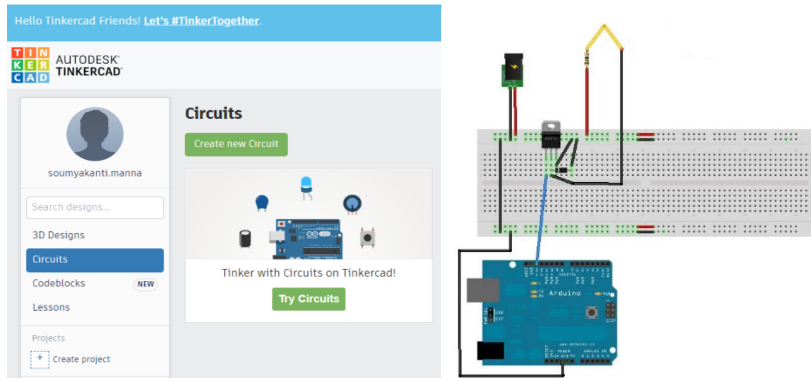

Figure 2. Building of Arduino circuit using Tinkercad software

FOUR STAGES OF DELIVERING CDIO PROJECTS

To deliver the programming oriented CDIO project online among students, we formed an indigenous way (Manna, Sheikholeslami and Nortcliffe, 2020) of pursuing it so that students could use the advantages of the CDIO framework in which they would get a chance to conceive an idea, design and develop a feasible and useful solution to implement that idea, operate the system/solution to evaluate its working function for additional adjustment and improvement of it. Four stages were involved in the process (Figure 3). Most importantly, students, first of all, perceived the current advancements in the field of science, designing, innovation and technology so that they could become familiar with the current technical issues with its prospective solutions. In the following stage, students were shown a few hobby projects with a basic engineering design and became acquainted with its engineering aspect so that they could analyse and interpret the reasonable conceptual link between a hobby project and industry-oriented design. They could also realise how an industry-standard item was formed, form a basic hobby design with specialised technical skill and engage in active learning support. In the last stage, students effectively took part in planning and delivering a CDIO project in a group with their fellow peers, which enhanced their teamwork capability making their decisions perfect based on a couple of suggestions. Finally, a feedback survey from the students was accumulated for critical reflection.

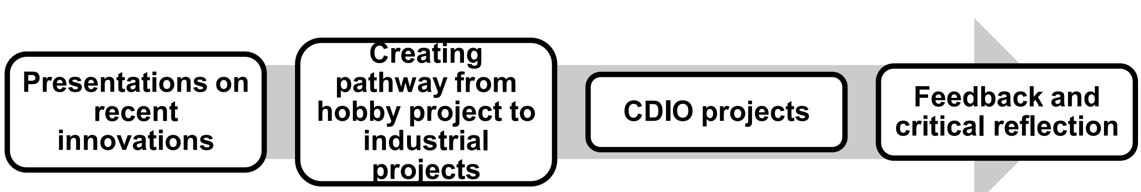

Figure 3. Stages of delivering CDIO projects

In this module, the CDIO project aimed to design and develop a line tracking robot with obstacle detection. Because of the limitation of conventional group work on campus, students were permitted to create a flexible online group in the blackboard collaborate platform following the think-pair-share method (Kaddoura, 2013) to investigate their thoughts (Figure 4). In blackboard breakout group sessions, students continued their discussion freely with team members, shared ideas and finally produced a collaborative outcome. Constructive criticism of ideas is always helpful for a group project. Through this technique, they enhanced their critical thinking on the project, improved their hands-on skill and teamwork. Students also used social media networks such as discord, WhatsApp and Facebook to continue their group work outside the scheduled sessions. Following the discussion, only one student in the group can build the hardware model although every member of the group contributed towards developing the final prototype from other areas such as mechanical design, electronics circuit and programming. Academic support was provided to individuals (on a one-to-one basis) and groups (using group practical session) through the Blackboard Collaborate tool. The Microsoft Team platform was used on specific occasions. There were several difficulties involved in making the prototype apart from face-to-face interaction such as purchasing components, financial support as well as motivation during the pandemic. Out of eight student groups, two student groups were successful in completing the project despite all the hurdles (Figure 4).

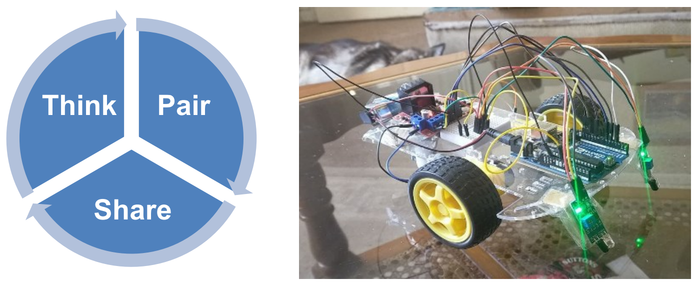

Figure 4. Virtual groupwork and developed CDIO project

ENGINEERING CAFE

In the cohort, a large number of students came from diverse backgrounds with varying cultural, ethnic and regional differences from across the world. Almost 30% of the cohort belonged to BAME (Black, Asian and minority ethnic) community. To support them psychologically beyond the academic environment, we arranged a weekly online cafe which was purely an informal chit-chat session for tutors and students. Due to the closing of the campus, students were socially confined and could not meet their peers physically. International students who had been staying far away from their family and could not travel back to their country due to lockdown were feeling alone and detached from their families and friends, which often created anxiety and mental illness among them. This type of initiative supported a comfortable environment among the students and a holistic learning framework where all students were invited and known to each other by name. It helped us to become familiar with the students as more than an academic bot, sometimes provide pastoral care, notice their interests and behaviours and create a sense of belonging.

DIGITAL POVERTY

Alongside the lack of face-to-face interaction and unavailability of practical sessions, one of the major problems in online learning is digital poverty. Many of our CCCU students could not afford the required IT equipment (Hi-spec laptops, headphone), hi-speed internet (for attending live lecture and practical sessions) to support online learning. This issue affected the students globally especially in underdeveloped and developing countries. In CCCU, the issue was partially resolved using several supporting arrangements such as:

- Hardship fund for students to support their online learning.
- Long-term laptop loan scheme where students can borrow a laptop for a long time.
- Recorded sessions for students to watch the lectures and practical later.

FEEDBACK AND CRITICAL REFLECTIONS

The learning material of the programming module was successfully delivered and covered all aspects of the learning outcomes as per the validation document. There were 32 students enrolled in the module. The average student attendance in the module was 80% before lockdown. Even during the lockdown, students were engaged in the module throughout the online learning sessions (Figure 5) and there was an opportunity for student participation in all four sessions. Follow up emails from students revealed that a few students were unable to join the sessions because either they struggled with digital poverty, had left for their home country, were medically unfit, or had started working as keyworkers.

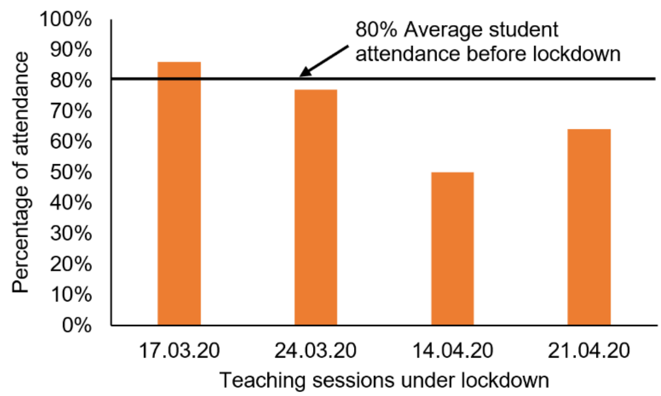

Figure 5. Engagement of students in online sessions

The module was supposed to be assessed by two assessments; coursework (40%) and CDIO project report (60%). Due to the university instructions, the submission of the CDIO project report was cancelled, however, the majority of the students completed the coursework. We also created a self-assessment online quiz to keep them engaged in the module. Overall, the performance of the students was satisfactory (Figure 6) considering the pandemic and circumstances; 63.63% of the students passed on their first attempt. . It was surprising to find that several disengaged students, who were detached from their course, engaged with the online sessions due to the flexible nature.

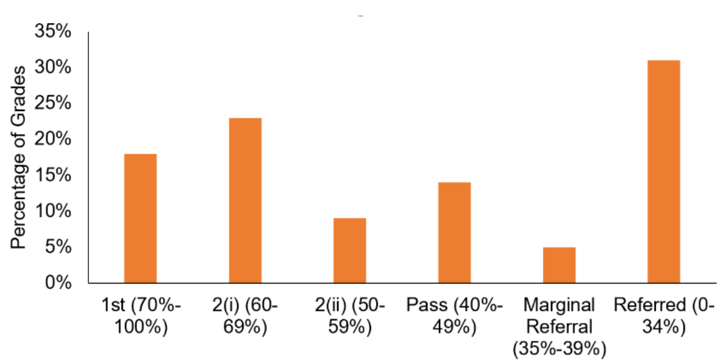

Figure 6. Performance of students in coursework

A few positive feedbacks from students are shown below about their learning experience.

From student 1

'I've enjoyed as much as I can your online lectures and feel it's going as well as it can do considering the circumstances......'

From student 2

'The lecture this morning was very useful and found that on the whole the format works as well as possible in the situation given…...'

A few negative feedbacks from students are shown.

From student 1

'The online lectures were less engaging than the face-to-face lectures and I found them harder to understand.'

From student 2

'Online lectures as they were harder to learn from. Unfortunately, i did not enjoy online learning as I work and learn better when teaching is face to face.'

CONCLUSION

Flexible online learning platform encouraged students to be adaptive during the pandemic through online live classes, virtual labs, recorded video and advance learning materials. Students obtained the advantages of synchronous learning (live session) and asynchronous (recorded video and material) learning. Informal sessions apart from academic classes helped the students to keep motivated in their personal life and engaged in the course. Moving forward in a post-vaccine or post-COVID-19 scenario, it will be an important question in the academic world whether to retain online learning or revert to face-to-face learning on campus. The student feedback revealed that they enjoyed all the classroom sessions, chats with tutors and peers as it kept them social and lively. Students learned new software tool which made their portfolio stronger for future project and career goal. They also had been trained on how to peruse CDIO project online and to achieve professional attributes. The engagement report was satisfactory in the online lecture and piratical sessions, however, they always prefer face-to-face session instead of online (retrieved from their feedback). During the online learning, students missed face-to-face interaction from tutors and social networking among peers. Additionally, it was challenging to manage the practical sessions and supervising students in the group work - particularly for the hardware projects. Although flexible online learning has proven to be beneficial during COVID-19, it should not be the ultimate solution in the future. The appropriate approach could be blended learning that is a combination of online and face-to-face learning to avail the benefits of both learning platforms. Many universities including CCCU undertook the blended learning policy from September 2020 onwards, we have endeavoured to keep on-site face-to-face contact hours with students to a minimum while maintaining all health and safety measures. It also provides students with flexibility in engagement with their learning as well as a safe environment. We have been delivering lecture sessions online and practical session on campus in a group of 15 cohorts to ensure the contact time is as little as possible. We enacted a one-way system of movement throughout the campus, provided hand sanitiser in each room and corridor, and had the staff move between rooms for the class session rather than the students in order to avoid the mixing of cohorts. This was based on the government guidelines for a COVID-19-safe campus. Based on this experience, it would be our recommendation to deliver theory-oriented modules online, where there is no need for on-campus lab equipment whereas the practical-oriented module should be facilitated through a combination of online learning (specifically lecture and tutorials and seminar) and face-to-face sessions where hardware equipment is required in order to provide hands-on training. In several experiments where large equipment was involved, practical experiments were conducted by tutor and students watched it online, recorded the experimental data and analyse it remotely. Although it did not allow students to do the experiments physically, students became familiar with the system and its working principle. We also recommend providing a space for informal social contact such as our engineering cafe to keep the students motivated and engaged in the process, either online or face-to-face, based on the situation. We are committed to finding innovative solutions to overcome current limitations to improve the student learning experience going forward.

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Engineering Education Research

STUDENTS' VIEWS OF SELF-REGULATED LEARNING STRATEGIES IN A BLENDED MODULE

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ABSTRACT

This paper seeks to contribute insights from an inquiry into how some students at Singapore Polytechnic (SP) viewed Self-Regulated Learning (SRL) strategies in a blended professional communication skills module in relation to their ability to manage their learning and self-development. SRL strategies may serve as drivers of students' ability to participate and develop in self-directed learning, and our findings indicated that respondents had positive beliefs about their value. However, these beliefs were rooted within conditions relating to the perceived practical value of the strategies for the given context and application, fit with personality, and ease-of-use, which informed or influenced students' choices of learning strategy. Although this paper did not originate within a CDIO context, and is not specific to engineering students per se, engineering students were among the multi-disciplinary mix of respondents in the study, and we find that our insights may hold relevance for CDIO Standard 2 learning outcomes, as presented in CDIO Syllabus v2.0 (Crawley, Malmqvist, Lucas & Brodeur, 2011) in terms of topic 2.4 (Attitudes, Thought and Learning), specifically 2.4.2 (Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility), 2.4.5 (Self-awareness, Metacognition and Knowledge Integration), 2.4.6 (Lifelong Learning and Educating), and 2.4.7 (Time and Resource Management). The insights may inspire us to give attention to how our students think and operate, help us reflect on the roles we play as educators, and offer some ideas as to the learning designs we might consider as well as other on-the-ground work that we need to do to support our students' cultivation of self-regulatedness, self-directedness and life-long learning.

KEYWORDS

Learning Behaviour, Learning Strategies, Self-Directed Learning, Self-Regulated Learning, Self-Regulated Learning Strategies, Standards: 2

INTRODUCTION

Singapore Polytechnic's School of Life Skills and Communication offers professional communication modules that support the holistic development of students across the institution, including those in our Engineering courses. The curriculum is blended to give students greater flexibility and control over their time and pace of learning, while encouraging self-directed and lifelong learning habits.

With less instructor supervision in blended learning, students must be more self-reliant and self-regulated to be effective in their learning (Broadbent, 2017; Broadbent & Poon, 2015; Kizilcec, Perez-Sanagustin & Maldonado, 2017; Pardo, Han & Ellis, 2016; You, 2016). Consistent with the literature, we observed that some of our students respond well while others flounder at managing their time and tasks, producing lower quality work and missing deadlines, or giving up altogether when they encounter difficulties with learning material (You, 2016).

To improve our ability to support our students' management of learning, we conducted an inquiry based on the introduction of nine Self-regulated Learning (SRL) strategies (Broadbent & Poon, 2015) in our Communication for Professional Effectiveness (CPF) module, which equips students with resume-writing and job-interview skills, and workplace etiquette.

We gained interesting insights into students' perceptions of SRL strategies, which we offer in this paper, together with ideas for addressing them, as a contribution to discussions of how to scaffold and support students' development of CDIO Standard 2 competencies, particularly:

- 2.4.2 Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility
- 2.4.5 Self-Awareness, Metacognition and Knowledge Integration
- 2.4.6 Lifelong Learning and Educating
- 2.4.7 Time and Resource Management

LITERATURE REVIEW

The Relevance of Self-Regulated Learning (SRL)

SRL is noted in education research for being essential to students' successful completion of their studies in higher education, and increasingly so in blended or online contexts (Broadbent, 2017; Broadbent & Poon, 2015; Kizilcec et al., 2017; Pardo et al., 2016; You, 2016). Of particular importance is the 'self-generated ability to control, manage, and plan their learning actions' (Ally, 2004, as cited in Broadbent & Poon, 2015, p. 2), which requires the learner to 'be motivated, meta-cognitively involved, and an active agent in his or her own learning process' (Zimmerman, 1986, as cited in Broadbent, 2017, p. 24), and to be competent in 'actively setting learning goals, employing effective and efficient learning strategies, making appropriate learning plans, adapting their approach from task to task, monitoring their learning persistently, and making adjustments when needed' (Pardo et al., 2016, p. 423).

Unfortunately, many learners are unable 'to maintain their motivation and persistence' and 'are characterized by their failures in estimating the amount of time and effort required to complete tasks and their lack of time-management and life-coping skills' (You & Kang, 2014; Yukselturk & Bulut, 2007, as cited in You, 2016, p. 23-24). This signals that we cannot assume all students come readily prepared for learning, and that they must be equipped with 'coping skills'.

It is also notable that 'SRL behaviours are not a static trait of students per se' and 'students may change their motivation and SRL behaviour and strategy depending on the nature of the course, its structure and the proposed learning activities' (Pardo et al., 2016, p. 423). This fluidity or complexity holds implications for how we interpret and act on students' learning behaviours as we must be mindful of the context and be flexible in responding to students.

SRL in Engineering Education

SRL has similarly been spot-lit in engineering education research. Nelson, Shell, Husman, Fishman and Soh (2015) argue that, ‘Engineering, like all disciplines, requires students to engage in self-regulated learning inside (e.g., note taking, question asking) and outside of the classroom (e.g., studying), and requires students to persist, even in the face of failure’ (p76), while Cervin-Ellqvist, Larsson, Adawi, Stöhr and Negretti (2020) point out that ‘the importance of developing effective SRL strategies is particularly evident for engineering students, who face a fast-changing work life with increasingly complex challenges’ (Hadgraft & Kolmos, 2020; Wallin & Adawi, 2018; Zheng et al., 2020, as cited in Cervin-Ellqvist et al., 2020).

It has also been noted that cultivating SRL in students is not a straightforward matter. Nelson et al. (2015) highlight that ‘consideration of multiple aspects of students’ motivation and their approach to learning is especially important for engineering education research’, as ‘students’ beliefs, perceptions, behaviours, and strategic approaches interact and affect each other’ (p. 92). Cervin-Ellqvist et al. (2020) echo these sentiments, noting that ‘students’ use of strategies has been shown to vary in response to their context of learning’ and that ‘strategies vary in effectiveness depending on materials, subject and the learners themselves… Clearly, there is some ambiguity about what students actually do when they use a certain strategy and why they use it, i.e. whether they use it because they (accurately or not) find it effective’.

The above arguments both invite and justify a closer scrutiny of how students understand and practise SRL and its strategies so that we can better support their efforts. To this end, we hope that insights from our inquiry may offer some clues to the student perspective.

SRL CAN AND NEEDS TO BE DEVELOPED IN STUDENTS

Sharp and Sharp (2016) assert that ‘many learners arrive at the postsecondary level academically underprepared; thus, development of learners’ self-regulatory capabilities is an important instructional component that leads to academic success’ (Bail, Zhang & Tachiyama, 2008; Gorga Cukras, 2006; Hu & Driscoll, 2013; Langley & Bart, 2008, as cited in Sharp & Sharp, 2016, p. 58). In engineering education, Cervin-Ellqvist et al. (2020) note that, ‘[SRL] learning strategies are seldom explicitly taught in HE’ (Bjork et al., 2013, as cited in Cervin-Ellqvist et al., 2020). The good news is that ‘SRL is not a fixed trait, but rather a skill that can be developed and honed through experience and practice applying SRL strategies’ (Azevedo & Cromley, 2004; Schunk, 2005; Zimmerman, 2015, as cited in Kizilcec et al., 2017, p. 19). Verma, Ahuja and Hermon (2018) conclude ‘after reviewing all the models of SRL that a learner can be helped in self-regulation through the understanding of SRL mechanisms’ (p. 8), while Pardo et al. (2016) advocate that we ‘instruct self-regulation directly so that students’ awareness of self-regulated learning can be raised’ (p. 426).

These perspectives hold relevance for how we might scaffold and support our students’ development of CDIO Standard 2 competencies, which relate to students’ ability to evaluate, adjust and persist in their learning endeavours. We offer some suggestions of actions to consider in the Discussion section below.

SLR STRATEGIES

There exists a substantial body of work constituting decades of research into SRL strategies (Panadero, 2017; Verma et al., 2018). We found Broadbent and Poon's (2015) meta-analysis, highlighting nine SRL strategies that correlate to 'academic achievement in online higher education environments' (p. 5), most relevant and practical for our context and purposes. The nine identified SRL strategies, as listed in Table 1 below, served as a resource for our students while allowing us to spotlight 'SRL strategies' and survey students on their perceptions.

Table 1. Nine SRL Strategies Correlating to Online Achievement (Broadbent & Poon, 2015)

SN	Strategy	Definition
1	Metacognition	'the awareness and control of mental thoughts'
2	Time Management	'the ability to plan study time and tasks'
3	Effort regulation	'the capacity to persist when confronted with academic challenges'
4	Peer learning	'collaborating with other learners in order to aid one's learning'
5	Elaboration	'the ability to use new and existing information with the aim of remembering the new material'
6	Rehearsal	'learning by repetition'
7	Organisation	'the ability to highlight main points during learning'
8	Critical thinking	'the ability to carefully examine learning material'
9	Help seeking	'obtaining assistance from instructors with the aim of overcoming academic challenges'

INQUIRY OVERVIEW

Our inquiry was carried out through:

1. An explicit introduction of SRL and a handout of '9 Self-regulated Learning Strategies' (accessible via https://bit.ly/31QPpxV) based on a synthesis of definitions and helpful SRL practices and behaviours described in Broadbent and Poon (2015) and Pintrich, Smith, Garcia and McKeachie (1991) administered during lessons in the second week of semester.
2. Two surveys administered at the start and at the end of the module respectively to obtain students' perspectives of SRL strategies, based on a convenience sample of 13 classes that included Aeronautical Engineering, Aerospace Electronics, and Electrical & Electronic Engineering students.
3. Data analysis, comprising the coding of verbatim text segments and descriptive statistics, based on 109 respondents who participated in both Surveys 1 and 2.

RESULTS AND OBSERVATIONS

STUDENTS' PERCEPTIONS OF THE USEFULNESS OF SRL STRATEGIES AT THE START OF THE MODULE

Figures 1a and 1b feature the SRL strategies that respondents reported using prior to CPF, and those they intended to use for CPF. Their reasons revolved around the following themes:

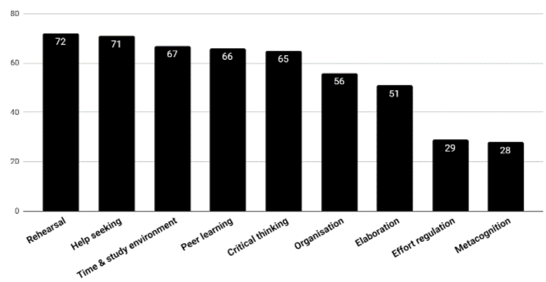

Figure 1a. Prevailing use of SRL strategies, ranked on number of responses.

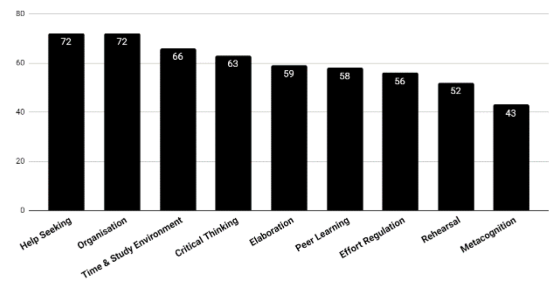

Figure 1b. SRL strategies respondents intended to use for CPF, ranked on number of responses.

1. Better management of self and tasks:
    a. improved organisation and tracking of work leading to higher efficiency
    b. better time management leading to less procrastination and less stress
    c. correcting bad habits (procrastination) and building good ones (self-discipline)

2. Benefits for self-development in terms of:
    a. monitoring and gauging one's performance
    b. building resilience, e.g., by trying different approaches and persisting
    c. holistic development, development as an independent learner, lifelong learning

3. Increased effectiveness and quality of learning in terms of:
    a. better thinking, understanding and retention of learning
    b. having greater control over learning, improved decision-making
    c. increasing one's confidence and capability to handle novel situations

4. Familiarity and ease-of-use in terms of:
    a. how 'intrinsic', 'natural' or 'automatic' the SRL strategies feel

5. Relevance to the context in terms of:
    a. meeting the SDL approach and outcomes of CPF (interpersonal skills)
    b. being most suitable 'for achieving successful and independent online learning'

From the above, we observed that respondents:

- seemed to hold largely positive beliefs of SRL strategies
- seemed to have an expectation that SRL strategies should be habitual
- believed the SRL strategies could benefit them in both the short and longer terms

Equally instructive were respondents' reasons for not using SRL strategies, namely:

1. 'Irrelevance', where SRL strategies were deemed:
    a. not applicable or effective
    b. not needed to do well

2. Unfamiliarity or difficulty with application where users:
    a. do not know about them/do not know how to apply them
    b. could not stick to them

The findings suggest that students' perceptions of the relevance, value and ease of use of SRL strategies are important factors that influence their choices.

Students' Knowledge and Use of SRL Strategies Reported at the End of the Module

Eighty-seven respondents (79.8%) reported that the knowledge or use of SRL strategies made a difference to the effectiveness of their learning in CPF, 16 (14.7%) were unsure, and 6 (5.5%) reported no difference.

SRL strategies appeared to enhance respondents' ability in five areas of self-regulation relating to perceived learning gaps in CPF (Figure 2).

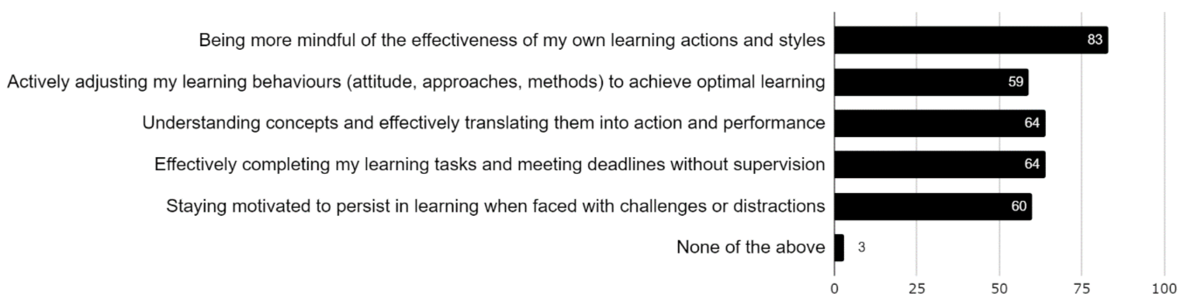

Figure 2. Perceptions of usefulness of SRL strategies in specific areas of self-regulation.

Ninety respondents (82.6%) said they would continue using SRL strategies, 18 (16.5%) were unsure, and 1 (0.9%) said s/he would not continue.

Ninety-one respondents (83.5%) said that they would recommend the use of the SRL strategies to other students, 17 (15.6%) were unsure, and 1 (0.9%) said that s/he would not.

Positive Perceptions of SRL Strategies

Respondents who responded positively in the above areas indicated that SRL strategies:
- increased their efficiency and effectiveness in learning, made learning/studying easier
- improved their ability to manage time and keep up/stay on track with work
- helped to produce quality work, yielded positive results in performance
- gave them a sense of satisfaction
- would help not only in their current and future studies but also in work and life

Notably, respondents reported a heightened sense of self-efficacy in terms of:
- self-development/improvement, e.g., being more confident, motivated and adept at work, more independent, organised, adaptable, proactive, and able to self-regulate
- increased awareness of learning, learning new skills, e.g., changing their thinking, seeing things differently, widening their repertoire of assessment approaches

Those who indicated that they would recommend SRL strategies felt the strategies:
- are of a wide variety suitable for different personalities and work attitudes
- help struggling students as a solution to procrastination and frustration with learning
- are in line with lifelong learning
- are easy to pick up
- should be brought to the attention of more students

Reservations or Doubts about SRL Strategies

Respondents who indicated they were 'not sure' in the above areas said they:

- found it difficult to judge the effectiveness of the SRL strategies
- were uncertain about being able to 'keep it up' or continue applying them consistently
- were unsure if SRL strategies would be applicable in other/future contexts
- did not find the SRL strategies particularly helpful in CPF or applicable
- were considering using 'other strategies'

Those who were unsure of recommending SRL strategies felt that:

- SRL strategies do not suit everybody and that it depends on a student's personality and how compatible they are with SRL strategies
- it is difficult to apply SRL strategies constantly and consciously, or they are 'tedious'
- others may have better methods to help themselves

Those who indicated that SRL strategies did not make a difference or would not recommend them noted that they:

- did not perceive a difference
- were not yet convinced of the usefulness of SRL strategies
- 'stuck to old habits'

Equally instructive were respondents' reports on the SRL strategies that they would have liked to use but did not in the end (Figure 3).

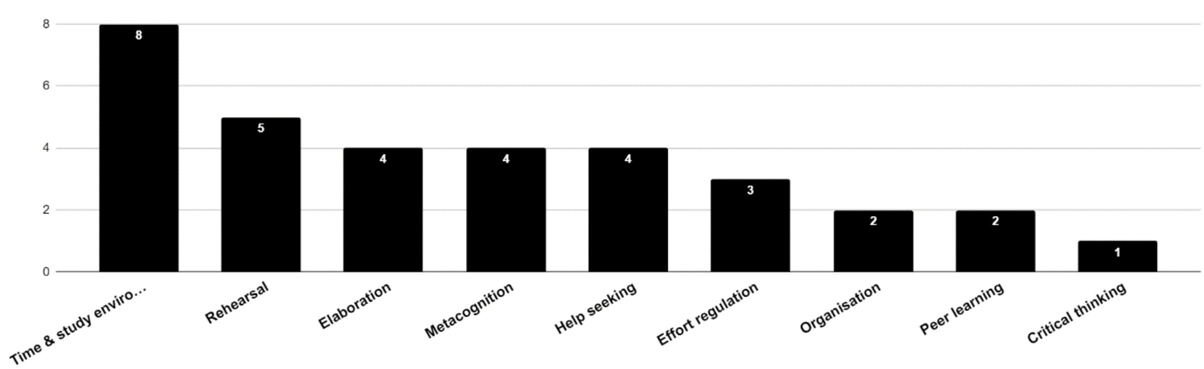

Figure 3. SRL Strategies that respondents did not use, ranked on number of responses

Respondents' reasons showed that they:

- were held back by lack of self-discipline, self-control or time
- had not yet mastered the strategy or made it a habit
- did not perceive a fit between SRL strategy and personality or learning style
- saw no relevance for application or did not have an opportunity to use an SRL strategy
- were frustrated by efforts, leading to failure to persist

A synthesis of the above themes and sentiments indicates that SRL strategies can benefit students in impactful, practical, even profound ways. However, users must deem them relevant, effective, applicable and practical. Ease-of-use, 'compatibility' with 'personality', and the ability to persist seem to be important deciding factors in their adoption of SRL strategies.

LIMITATIONS

There are several limitations to our study. We did not use a validated instrument for our surveys and based our study on self-reported data, which may not 'properly represent actual self-regulated learning behaviours in authentic learning contexts' (You, 2016, p. 23). Furthermore, we did not explore a more complex conception of SRL and how 'moderating factors work together with SRL strategies to influence academic achievement' (Broadbent & Poon, 2015, p.12), thus our interpretations are limited by our assumptions. Respondents' answers to our open-ended questions were at times brief or unclear, affecting our ability to completely or accurately interpret reasons or rationales. In addition, some students did not have a complete understanding of terminology, raising questions about the accuracy of their responses. Finally, we relied on a convenience sample that may not be generalizable to the population.

DISCUSSION

We drew two key lessons from our inquiry, and attempt to draw connections as well as suggest practical applications in synthesis with CDIO Standard 2 learning outcomes, specifically those under 2.4.2, 2.4.5, 2.4.6 and 2.4.7, in the discussion below.

SRL Strategies can Benefit Students in Impactful, Practical, even Profound Ways

Our findings indicate that introducing SRL strategies explicitly would make a difference to students' management of learning, as it makes visible to them some means of addressing their learning challenges and cultivating effective learning habits for lifelong learning. Our respondents signalled that they became more aware of how they manage themselves and their learning, with a majority reporting both short- and long-term benefits in:

- self-, time- and task-management,
- self-awareness, self-efficacy and self-development,
- effectiveness, quality, satisfaction and knowledge of learning

Some respondents were conscious of using the SRL strategies to adjust to a more independent way of learning, e.g., 'It pushes me to do work consistently and have a self-check on where I am, hence being more independent with my own studies', while others were able to leverage specific SRL strategies to their advantage, e.g., 'I was able to apply [Time & Study Environment] in terms of planning ahead of time what are the tasks needed to do by looking at the module map…. Another example includes having set reminders either in my calendar or an app to remind myself of what I am required to do helps me manage my time more easily'.

These outcomes embody many of the desired traits outlined in CDIO Standard 2, which include such competencies as responsibility and determination to accomplish objectives, adaptability, skills to assess and take action for self-improvement, habitual exercise of metacognition, and ability to manage resources for optimal learning (Crawley et al., 2011) – in essence, students becoming more empowered and self-directed as learners. This suggests that it would be profitable for us to provision students with relevant SRL strategies to support their development of said CDIO Standard 2 competencies, to which end we offer suggestions in Table 2 below.

A Complex Interplay of Factors Underlies Students' Decisions to Use SRL Strategies

We must be cognizant, however, of the complex interplay of factors underlying students' use of SRL strategies and this, in our opinion, is the more striking lesson. Extending views we noted earlier from Pardo et al. (2016), Nelson et al. (2018) and Cervin-Ellqvist et al. (2020) on the complexity of student learning behaviour, our findings suggest that SRL strategies can be impactful but must be deemed relevant, practical and effective in users' contexts. They are contingent on whether the strategies 'fit' with personality or learning style, and there appears to be an implicit belief that SRL strategies should 'come naturally'. Users may give up if they encounter difficulties in the mastery of a strategy or if 'too much effort' is required.

This points to rather intuitive decision-making processes on our students' part. SRL strategies may serve as drivers of students' ability to participate and develop in self-directed learning, however, they appear not to be just a means to an end, but an experience that learners choose to undergo as a discrete part of their lives, with any choice made intimately tied to their identity. It is part of their 'way of being' (Walther, Miller & Sochacka, 2017). This implies that knowledge of 'what to do' may not necessarily lead to application if a learner does not perceive a fit with his/her 'self-concept', and suggests that the design and execution of any instruction on SRL strategies must recognise students' sense of 'self' and address students' motivations and barriers as a context for the introduction and use of SRL strategies.

In practical terms, 'teachers have to take learning context and other factors (e.g. all areas of Pintrich's model of SRL) into consideration to develop suitable educational approaches to scaffold students' learning effectively…, a scaffolding that is often very limited as teachers tend to focus on the course content' (Dunlosky & Rawson, 2019, Moos & Ringdal 2012, as cited in Cervin-Ellqvist et al., 2020). Underscoring the important facilitative role of teachers, Van Laer & Elen (2017) note how 'learning and performance are improved by facilitating learners' use of adaptive self-regulatory learning strategies' (p. 1406-1407). This suggests that, in the midst of content instruction, we should also give attention to facilitating students' evaluation of their learning gaps, mindfully coaching students to shift their perspectives when they are unable to adjust their learning behaviours or choices, suggesting more appropriate learning strategies for the context, coaching them in the effective application of a strategy, and giving opportunities for practice and recording results so that students may receive feedback that allows them to continue improving their attitudes, approaches and processes for learning. We outline some of these ideas in explicit relation to CDIO Standard 2 competencies in Table 2 below.

Table 2. Ideas to Support Students' Growth in CDIO Standard 2 Competencies

CDIO Standard 2 outcomes (refer to Crawley et al., 2011 for full list)	SRL strategies that may help	Practical steps for teachers
2.4.2 Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility	Awareness of strategies like 'Effort Regulation' can help learners consciously increase their 'determination to accomplish objectives'.	Encourage and coach students to recognise their personal barriers to perseverance, regulate themselves and exercise flexibility in their learning approaches.
2.4.5 Self-Awareness, Metacognition and Knowledge Integration	Knowledge and use of 'Metacognitive Self-regulation', 'Elaboration' and 'Organisation' can help learners find ways to be more self-efficacious at 'overcoming important weaknesses,' and to 'link knowledge together and identify the structure of knowledge'.	Provide guided examples and exercises for practising 'Metacognitive Self-regulation'; facilitate the construction of new knowledge by coaching students to actively use strategies like 'Elaboration' and 'Organisation' within your specific lesson context.
2.4.6 Lifelong Learning and Educating	Making the wide range of learning strategies visible to learners should help them become more aware of their own learning style, recognize that choices are available, and begin to develop a repertoire of 'skills for self-education'.	Help learners diagnose their learning gaps, remind them that it is important to develop a repertoire of 'skills for self-education', and offer suggestions to aid the expansion of such knowledge.
2.4.7 Time and Resource Management	Strategies and steps for 'Organisation' of content for learning and mindfully adjusting or controlling 'Time and Study Environment' should provide ideas for learners to prioritise and fulfil tasks.	Make reminders and suggest tools (e.g., use of calendars and alerts, productivity apps) for students to organise and manage their 'Time and Study Environment' effectively for a given context.

CONCLUSION

This paper has attempted to contribute discussion points for the development of engineering students' Personal and Professional Skills and Attributes, with specific focus on learning outcomes under CDIO Standard 2 Topic 2.4 Attitudes, Thought and Learning (Crawley et al., 2011), through the lens of SRL and its strategies. While our initial intention was to 'contribute', in the end it is we who have gained valuable learning and a major insight for ourselves: it is the realisation that the learning outcomes specified in CDIO Standard 2 are not just 'desired outcomes' but the very foundations on which learners may thrive in their learning, that is, the ability to wisely make judgements about themselves, to have the means to make suitable adjustments, and the drive to be life-long learners. We believe these foundations must be deliberately integrated and explicitly built with a keen understanding of the way learners perceive themselves and their learning choices, accompanied by an appropriate provision of resources, such as relevant SRL strategies, and coaching to allow learners to evaluate themselves and their learning choices. Therein lies our challenge as educators, but if we are able to do this well, the value to our learners could be immense, not only in their studies, but for life.

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ORAL GROUP EXAMINATION METHOD TO EVALUATE COLLABORATIVE AND INDIVIDUAL LEARNING

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ABSTRACT

The engineering education at Aarhus University, Denmark, includes the course Statistics and Design of Experiments (DoE) that encompasses both collaborative and individual learning activities. The choice of examination method is important, as students adapt their learning behavior accordingly. Group examinations align well with collaborative learning and individual examinations are successful in assessing individual learning and detecting free riders. To avoid organizing and exposing the students to two examinations and thus imposing additional undesirable costs, we aimed to develop a single highly structured oral group examination method that addresses both collaborative and individual learning in an organized fashion without increasing demands on academic staff. The oral group examination method described in this study is a three-in-one exam where all group members in a project group are present at all times. First, the students' collaborative skills were addressed with focus on knowledge application and analysis. Then their individual skills were addressed with focus on basic knowledge understanding. Finally, students were given the opportunity to evaluate their own knowledge and create new knowledge, which includes the pinnacle of Bloom's taxonomy pyramid. The examination method was tried out with four classes of engineering students (142 in total): two Chemical engineering and two Biotechnological engineering classes in their second and third year. Afterwards, students reflected on their perception of the exam in a survey. In summary, the examination method embraced assessment of both collaborative and individual learning and provided time for in-depth discussions with all group members, in the project group, on a high taxonomic level. We encourage other educators to explore this examination method. The present study includes a "ready-to-implement" protocol and a "ready-to-use" Student Scoring Sheet to keep track of the contribution of each student.

KEYWORDS

Second-Year Undergraduate, Chemical Engineering, Biotechnology Engineering, Testing/Assessment, Student-Centered Learning, Standards: 11

INTRODUCTION

Statistics and Design of Experiments (DoE) is a mandatory course for Chemical and Biotechnological Engineering students at Institute of Biotechnology and Chemistry, Aarhus University, Denmark. The course encompasses both collaborative and individual learning activities. During the collaborative activities, the students are divided into groups, where they actively engage in a problem-based-learning (PBL) activity based on a selected project within DoE. In addition, the students attend traditional lectures and work individually or in groups with exercises concerning theory on statistical methods. Prior to the exam, the students hand in a project report describing their results. Until recently, in order to asses and certify the students' acquired course skills, the course was concluded by conducting a single final individual oral exam.

From 2006-2013, group exams were discontinued in all educational institutions in Denmark. This decision was made due to concern that grade distinctions among students were too blurred in group exams. That is, low-performing students were awarded grades that were too high, while high-performing students were awarded grades that were to low (Krogh & Jensen, 2013). Thus, individual exams replaced all group exams during this period. In an attempt to assess collaborative learning in courses containing project-organized PBL activities, some individual oral exams would include a group presentation prior to the individual examination of each group member, whereas others would rely solely on an individual examination. The many years without group exams left students and educators, especially the younger ones, unfamiliar with the group examination format. Prior to the reinstatement of group exams, studies among students revealed that students generally did not feel confident about the validity of a group exam (Krogh & Jensen, 2013). The students worried whether the examiners were able to give reliable and valid individual grades when other group members were present. They also worried that some students would dominate the exam. After years of individual exams the reinstatement of group exams has led to an increased focus on how the students are examined and what they are examined in. Thus, in order to be successfully reinstated, group exams require a renewal process, where group exam procedures are explicated and exemplified more clearly to both students and educators.

The objective of the present study was to develop such an oral group examination method. The examination method should be highly structured and utilize the benefits of the former oral group exam and the current oral individual exam. It should embrace both a group and an individual assessment aspect and ensure the following: 1) time for in-depth group discussions to evaluate the students' ability to collaborate, 2) the ability to assess each student individually, 3) the possibility of detecting free riders, 4) time for the students to reflect on and evaluate their acquired knowledge and create new knowledge, and 5) the possibility of addressing all knowledge levels in Bloom's taxonomy pyramid in a structured manner (Bloom, 1956, 2001). The idea is that more students will demonstrate skills at the pinnacle levels of Bloom's taxonomy when other group members are present to fill in underlying and indispensable knowledge gaps. Finally, the examination method should be conducted without increasing demands on academic staff.

In our highly structured oral group examination method, the total examination time of all students in the group is compiled into one exam, which is then divided into three parts (Figure 1). Part one is a group examination. Part two explores the actual level of understanding of each individual student. Part three is a group reflection, allowing time for the students to evaluate their own knowledge and possibly create new knowledge. Our hypothesis is that this highly structured oral group examination method will lead to sound and valid assessment of the students' acquired course skills at several levels of understanding.

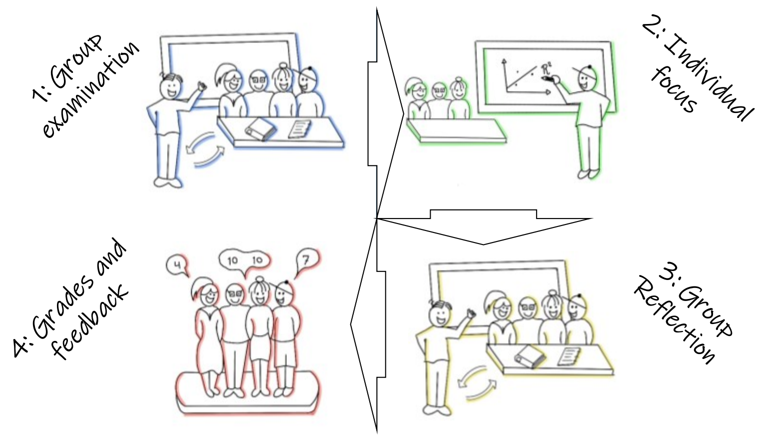

Figure 1. Graphical presentation of the highly structured oral group examination method. 1: shows a group examination where the examiner addresses all students in a group. 2: shows focus on one student to explore individual level of understanding. 3: shows a group reflection where the examiner addresses all students in a group. 4: shows students receiving grades and feedback after the examination

The highly structured oral group examination method was tried out with four classes of engineering students. Subsequently, the students were asked to reflect on their perception of the examination method in a survey. On average, the students obtained grades above a 7 (corresponding to a C) and perceived a maintained ability to perform individually, a valuable experience in being examined both collaboratively and individually in the presence of their group members, and felt that the exam was fair. There was no additional time spent per student, and the examination method provided extended time to address the learning outcomes more thoroughly and, thus, to assess the students in a more satisfactory manner.

In this paper, we present our highly structured oral group examination method, which aligns well with courses comprising both collaborative and individual learning. It also works well with courses with limited time per student for the final examination. In contrast to the traditional individual oral examination, where time is short and the questions are interrogation-like, the authors experienced more time for dialog and thorough group discussions in the oral group examination method, as well as the possibility of addressing higher taxonomic levels of knowledge. All of this is achieved in a highly structured fashion.

Based on the present study, we encourage other educators to explore the highly structured oral group examination method. To assist implementation, this paper includes a “ready-to-implement” protocol (Table 1) together with a “ready-to-use" Student Scoring Sheet (Supplementary material) to ease the task of keeping track of each individual student’s contribution during the examination.

CONTEXT

Statistics and Design of Experiments (DoE) is a 5-ECTS (European Credit Transfer System) course, which makes up one sixth of a typical semester. It comprises 14 four-hour teaching modules, with one module scheduled each week. The first half of the modules are carried out by giving traditional lectures and assisting the students in solving problems, either individually or in groups. These modules focus on theory on statistical methods such as parametric hypothesis testing including analysis of variance (ANOVA) and linear regression, non-parametric hypothesis testing, and how to use control charts to assess whether a process is in a state of statistical control. The last half of the modules are carried out by supervising a PBL activity, where the students are divided into groups and work collaboratively on a selected project within DoE. These modules focus on factorial design and response surface methods (RSM). To complete the project, the groups write and submit a mandatory report of around 10-15 pages prior to the exam. The course learning outcomes address the higher taxonomic levels of knowledge and specify that the students should be able to apply their acquired knowledge, analyze their data, evaluate their results and suggest experiments that would improve their results, it they were to perform the project again.

Four classes of engineering students comprising second- and third-year Chemical and Biotechnological Engineering students (n = 142) attended the course in the spring semester of 2018: two second-year classes, Chemistry [n = 34] and Biotechnology [n = 35], and two third-year classes, Chemistry [n = 31] and Biotechnology [n = 42]. Students were assigned into groups consisting of three to six students: three groups of three students, three groups of four students, 17 groups of five students and six groups of six students. In the second-year classes, students were randomly assigned, and in the third-year classes, students were self-assigned. The learning outcomes were the same regardless of how many students joined a group, whether the students were second- or third-year, or whether the students were Chemical or Biotechnological Engineering students. During the PBL activity, the purpose was to create a final equation describing the variation in a chosen process outcome and furthermore understand the sequential line of events that lead to this equation. The submitted report was a prerequisite for taking the exam, but did not count in the final grade.

At the beginning of the course, the students were informed that the final exam would be an oral group exam, where they would be evaluated both collaboratively and individually, and that grades would be given individually. Course settings allocated a total of twenty minutes per student for the final examination. Accordingly, the highly structured oral group examination method was allocated the total time of the number of students times twenty minutes. The six groups of six students were randomly split into two groups of three students, prior to the exam, in order to reduce the total examination time and to be able to keep track of all students. Thus, the shortest exam was one hour (three students) and the longest exam was one hour and 40 minutes (five students). To illustrate the examination method, a small-scale trial exam was conducted together with the students in class prior to the final exam. Two educators were present for this illustration and volunteer students pretended to take the exam. After the trial exam, the students were given the opportunity to ask questions about the exam.

EXAMINATION METHOD

The highly structured oral group examination method consisted of three parts, in addition to the part where grades and feedback were given (Figure 1 and Table 1). Two academic staff members were present during the exam; one acting as an examiner and the other as a co-examiner. Part one (six minutes per student) was a group exam based on the project report submitted by the students. Here, the students discussed how their acquired knowledge was applied in their project, what choices were made, which obstacles were encountered, and how their data were analyzed. To make sure that all students contributed evenly to the group discussion, the students were instructed to divide the allocated examination time among them and were encouraged to raise their hand to indicate the possession of a possible answer. The co-examiner, who kept track of time, guided the discussion by asking supplement questions as needed. In this part of the exam, the examiners developed a first impression of each individual students' level of understanding. Following part one, all students left the room while the examiners evaluated the students' midway performances and decided on a strategy to challenge or affirm each individual student's level of knowledge.

After the evaluation intermission all students re-entered the room. Part two (six minutes per student) of the exam then explored the actual individual level of understanding of each student. Each student randomly selected a question for examination from a pool of questions covering the theory on statistical methods taught in the course. In turn, each student was examined. Upon request from the student or the examiners, the student was able to receive help from the group members. Group members were then allowed to rephrase the questions or provide useful hints on how to answer the questions, but they were not allowed to give actual answers. In order to attain positive grading, each individual student still had to answer their own examination question. Thus, this part of the exam covered individual assessment and the detection of potential free riders, which is a benefit of the traditional individual examination. Moreover, group members were present to reduce anxiety, which is a benefit of the traditional group examination.

Part three (three minutes per student) was conducted in the same way as part one, but with focus on reflection, which allowed time for the students to evaluate their own knowledge and possibly create new knowledge. To keep record of the students' responses during the exam, a Student Scoring Sheet (Supplementary material) was employed. If the students raised their hand to indicate the possession of a possible answer or if they rephrased a question or provided a hint to a fellow student, this was recorded in their favor. Following part three, once again, all students left the room and the examiners carried out a follow-up/final evaluation. Finally, part four consisted of grading and feedback, which was given either individually or to the whole group. Altogether, the intermediate evaluation, the final evaluation, grading and feedback were allocated a total of five minutes per student.

All students were graded individually and grades were based solely on their performance during the examination. The Danish "7-point grading scale" system was used, where the grades 12, 10, 7, 4, 02, 00, -03 correspond to the following grades on the ECTS scale: A, B, C, D, E, Fx, and F, respectively. Immediately after grading, the students were asked to participate in a survey, designed by the authors, where they were asked to reflect on their perception of the examination method by filling out a questionnaire. The questionnaire comprised five questions (Figure 2, Q1-5) and the possibility of adding additional comments. The questions were presented as statements, where the students rated their perception anywhere on the scale from "I disagree" (-100%) through "I neither disagree nor agree" (0%) to "I agree" (100%). The statements "I had ample opportunity to say what I wanted" (Q1) and "It felt comfortable receiving individual questions in the presence of the other group members" (Q3) were used to evaluate whether the students experienced a sufficient ability to perform individually. The statement "There was support in receiving and answering questions as a group" (Q2) was used to evaluate whether the students felt supported in being examined through dialog and discussion among group members and examiners. The statements "The examination form was fair" (Q4) and "I prefer this group examination method in comparison with the one I am used to, where the first part is a collective group presentation of the project followed by an individual examination" (Q5) were used to evaluate whether the students experienced alignment between learning outcomes, activities and assessment. It is worth noting that all second- and third-year Chemical and Biotechnological Engineering students had completed two to three project exams prior to their exam in Statistics and Design of

Experiments (DoE) where the format comprised presenting their project collectively as a group prior to a traditional individual oral exam.

Table 1. A “ready-to-implement” protocol for the highly structured oral group examination method for groups of four students

Part	Examination goals	Procedure
1: Group examination 24 minutes (6 minutes/student)	Collaborative skills. (Based on PBL activity)	All students are expected to participate actively in the discussion on how acquired knowledge is applied and used to analyze obtained data.
	Evaluation intermission[a]	
2: Individual focus 24 minutes (6 minutes/student)	Individual skills. (Based on theory)	Each student randomly chooses a question and is responsible for answering and demonstrating individual level of understanding. Group members are allowed to rephrase questions or provide useful hints.
3: Group reflection 12 minutes (3 minutes/student)	Collaborative skills. (Based on reflective questions)	All students are expected to participate actively in the discussion and evaluate acquired knowledge and create new knowledge.
	Evaluation[b]	
4: Grades and feedback[c]		Grades are given individually to each student with minor feedback or to the whole group with more time for feedback.

Prior to examination, names of all students are recorded on the Student Scoring Sheet (Supplementary material) to keep record of each individual student’s responses. [a,b]All students are asked to leave the room and the examiners make a first[a] and a follow-up/final evaluation[b]. [c]Part 4: Grades and feedback and the two evaluations share the remaining examination time: 20 minutes (5 minutes/student). Students are given the opportunity to make commentary notes during the exam. PBL = Problem-based learning.

Statistics

One-sample t-tests were used to test whether the grades were above 7 (C), if the grade distribution followed the normal distribution, and whether the students agreed more to a question in the questionnaire than “neither disagree/nor agree”. One-way ANOVA tests were used to compare grades in the four classes (second- and third-year, Chemical and Biotechnological Engineering students, and groups of three, four, or five students). Two-way ANOVA tests were used to take into account whether the students were second- or third-year students and studying Chemistry or Biotechnology. Linear regression analyses were performed to test for correlation between survey responses and grades. $p < 0.05$ was considered significant.

RESULTS

The 142 students who participated and completed the highly structured oral group examination method were graded 7.8 ± 3.1 (mean ± std. dev.) in average, which was significantly higher than the overall average of 7 (C, $p = 0.003$). The grades awarded to the four classes were distributed as follows: 4% ±

2% attained grade 2 (E), 24% ± 8% attained grade 4 (D), 28% ± 5% attained grade 7 (C), 25% ± 7% attained grade 10 (B) and 18% ± 8% attained grade 12 (A). No students failed the course (grades 00 (Fx) and -03 (F)). No significant differences were seen in the grades between the four individual classes, between second- and third-year students, nor between students studying either Chemistry or Biotechnology. Although grades are awarded solely based on the student's fulfillment of the learning outcomes, it is expected, for a large population of students, that the grade distribution will follow a normal distribution. In the normal distribution, 10%, 25%, 30%, 25% and 10% attain the grades 12, 10, 7, 4 and 02, respectively. The failing grades 00 (Fx) and -03 (F) are not included in the expectations for a normal distribution. For the four classes participating in the oral group examination method, there were no significant deviations from the expected grade distribution, except that significantly fewer students were given the grade 02 ($p = 0.011$). In addition, the average grades obtained in the examined groups of three, four, or five students were not significantly different.

Immediately after grading, the students were asked to participate in a survey where they were asked to reflect on their perception of the oral group examination method. All survey responses are summarized in Figure 2. The students significantly agreed on: having ample opportunity to say what they wanted (Q1, 33%, $p < 0.000$), experiencing support in receiving and answering questions as a group (Q2, 44%, $p < 0.000$), feeling comfortable receiving individual questions in the presence of the other group members (Q3, 37%, $p < 0.000$), and experiencing that the exam was fair (Q4, 29%, $p < 0.000$). When comparing the group examination method with the examination method used in previous semesters in other courses, where students give a collective group presentation of their submitted project report prior to a traditional individual oral exam, the students did not significantly agree or disagree on which examination method they preferred (Q5, 10%, p = 0,061).

The students' grades and their answers to Q1, Q2, and Q4 correlated significantly (Q1: $p = 0.001$, Q2: $p = 0.024$, and Q4: $p = 0.002$). Thus, students receiving higher grades were more likely to agree on having ample opportunity to say what they wanted, experiencing support in receiving and answering questions as a group, and experiencing that the exam was fair (data not shown). Interestingly, second-year students were more likely to agree on having ample opportunity to say what they wanted (Q1, $p = 0.031$) and on experiencing that the exam was fair (Q4, $p = 0.001$) in comparison with third-year students (data not shown). In addition, Biotechnological Engineering students were more likely to agree on experiencing that the exam was fair (Q4, $p = 0.005$) in comparison with Chemical Engineering students (data not shown).

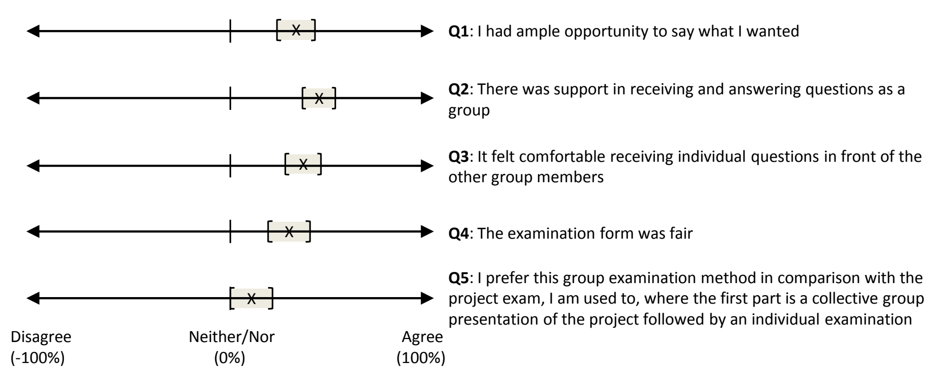

Figure 2. Survey questions and summary. The students were asked to reflect on the group examination method by filling out a questionnaire handed out immediately after grading. All brackets display the mean response values (X) together with a 95% confidence interval. **Q1:** mean = 33%, [24%;42%]; **Q2**: mean = 44%, [36%;52%]; **Q3:** mean = 37%, [28%;45%]; **Q4**: mean = 29%, [19%;39%]; **Q5:** mean = 10%, [0%;21%]). Data were based on completed questionnaires from all 142 participating students.

In the questionnaire, the students provided several additional comments regarding the group examination method. Of the 142 students: 20 explicitly commented that raising their hand to emphasize the possession of a possible answer worked well, 14 explicitly commented that they liked that other group members could assist them in answering a question, nine explicitly stated that this oral group examination method only worked well, when the dynamics of the group were good; Eight explicitly suggested that the individually chosen questions for the second part of the exam, should not be revealed before time of addressing. This, in order to avoid that group members focus more on their own question and, consequently, pay less attention to the question being addressed by the group member being examined; six explicitly stated that more than five students in a group exam, would be too many.

DISCUSSION

Pedagogical research strongly recommends that course objectives and activities align with the method of examination, as students adapt their learning behavior accordingly (Bretz, 2012; Brown & Glasner, 1999; Momsen et al., 2013; Pienta, 2011; Rhodes, 2010). The objective of the present study was to develop a highly structured oral group examination method that aligned with the current course comprising both collaborative and individual learning. The examination method should meet the demands for clearer explication of the rules for carrying out a group exam and ensure exemplification of the exam format to ensure transparency and confidence among students and examiners. At the same time, the examination method should result in reliable and valid individual grading, without causing additional time-use per student.

Other studies have reported on the combination of group and individual exams, but mostly in a written format where students answer free response problem-solving questions, essay questions or multiple-choice quizzes. In fact, the written two-stage examination method has been widely used for final assessments. In this type of exam, one stage involves an individual part and a second stage involves a collaborative part. For instance, students may hand in an individual response prior to addressing identical or similar questions collaboratively as a group (Levine et al., 2018; Levy, Svoronos, & Klinger, 2018; Lindsley, Morton, Pippitt, Lamb, & Colbert-Getz, 2016; Mahoney & Harris-Reeves, 2017; Rieger & Heiner, 2014; Rivaz, Momennasab, & Shokrollahi, 2015; Vázquez-García, 2018; Wieman, Rieger, & Heiner, 2014). Others have used written group exams as midterm assessments to supplement a final individual exam (Bay & Pacharn, 2017), have offered voluntary group retakes of exams at a later time point following an individual exam (LaBossiere, Dell, Sunjic, & Wantuch, 2016), or have allowed students to work together on a written group exam prior to taking a separate individual exam (Siegel, Roberts, Freyermuth, Witzig, & Izci, 2015). Some studies report a positive effect on the overall average score as a consequence of including a collaborative aspect in the exam (Hanna, Roberts, & Hurley, 2016; Levine et al., 2018; Rivaz et al., 2015; Vázquez-García, 2018), whereas others fail to find an overall effect (Mahoney & Harris-Reeves, 2017), or even find a negative effect (Molsbee, 2013). Interestingly, studies dividing students into high and low performers or dividing questions into basic/concrete and complex/abstract categories report that low performers' grades increase more than high performers' and that answers to complex questions improve more than answers to basic questions when a collaborative aspect is included in the exams (Bay & Pacharn, 2017; Levy et al., 2018; Mahoney & Harris-Reeves, 2017; Siegel et al., 2015). It is important to note, however, that even high performers are reported to improve from collaboration (Jang, Lasry, Miller, & Mazur, 2017). Moreover, it has been suggested, that group exams improve learning, improve knowledge retention and reduce exam anxiety. Downsides, however, have also been reported and include: 1) retrieval disruption, where students forget due to interruptions, 2) production blocking, where students wait their turn and therefore halt ideas, 3) shared forgetting, where all students in a group overlook the same knowledge, or 4) spreading of misinformation (LoGiudice, Pachai, & Kim, 2015). In addition, some students become stressed when working in the presence of other students (LaBossiere et al., 2016).

In the present study, the students obtained average grades above 7 (C), and no students failed the course. Implementing the highly structured oral group examination method does not seem to have a negative impact on the final grades. It is worth noting, that the group examination part in the highly structured oral group examination method accounts for more than half (6 minutes of collaborative testing plus 3 minutes of collaborative reflection versus 6 minutes of individual testing per student) of the final grade, whereas other studies report a group examination part accounting for only 5% (Levine et al., 2018), 10% (LaBossiere et al., 2016) or 33% (Rieger & Heiner, 2014). In addition, average grades were not significantly different when compared with grades obtained at the individual oral exam used prior to changing to the present group examination method (n = 48 students).

It is unusual, however, that no students failed the course, although, we generally experience a low percentage of students failing this course. We believe that the mandatory report, which is a prerequisite for taking the exam, is of crucial importance. This report sums up the acquired knowledge from the collaborative PBL activity, which covers at least half of the course. If students do not participate actively in the PBL activity, it is difficult to be part of a group report and consequently join the exam. On the other hand, if students participate actively, they spend at least half of the course in collaboration with other students collectively acquiring course knowledge. Moreover, weekly group supervisions most likely improve learning skills through the possibility of discussing difficult learning outcomes with both the group and the teacher.

After the exam, the students were asked to participate in a survey to reflect on their perception of the highly structured oral group examination method. All students responded, rendering great credibility and validity to the interpretation of the response data. Firstly, the students replied that they "experienced ample opportunity to say what they wanted" (Figure 2, Q1), and "felt comfortable receiving individual questions in the presence of the other group members" (Figure 2, Q3), which suggest that being examined as a group did not hinder the students' experience of being able to perform individually. Secondly, the students "experienced support in receiving and answering questions as a group" (Figure 2, Q2). Undoubtedly, this feeling strongly depends on the existence of well-functioning group dynamics, which was also noted explicitly by nine students in the survey. Interestingly, the authors experienced that, in some groups, resourceful students were able to elevate the performance of the entire group by rephrasing questions or providing helpful hints, but not actual answers during the exam, a phenomenon most likely correlated with favorable group dynamics. Finally, the students "felt the exam was fair" (Figure 2, Q4). This was especially true for students who attained higher grades. That the exam felt fair suggests that the students felt alignment between learning outcomes, activities and assessment. This may correlate with the fact that the students "neither favored nor disfavored" the oral group examination method in comparison with the project examination method, where students give a collective group presentation prior to a traditional individual oral exam" (Figure 2, Q5), as the project examination method also displays both a collaborative and an individual examination aspect.

Considerable research has been reported on reduced anxiety in group exams compared with individual exams (Caldecott & Emmioglu, 2017; Levy et al., 2018; Siegel et al., 2015; Vázquez-García, 2018). Although not directly addressed in this study, the students responded in the survey that they “felt comfortable receiving individual questions in the presence of the other group members” (Figure 2, Q3) and that they “experienced support in receiving and answering questions as a group” (Figure 2, Q2), which may suggest that the students experienced a low level of anxiety. This may explain, in part, the positive manner in which the students have embraced this oral group examination method with which they have minor or no previous experience.

Interestingly, the Biotechnological Engineering students and the second-year students agreed more on experiencing a fair exam in comparison with the Chemical Engineering students and the third-year students, respectively. The amount of group work presented to the Biotechnological and Chemical Engineering students is the same during their semesters. However, only the Biotechnological Engineering students have previously attended a group exam, whereas the Chemical Engineering students have not. The group exam tried out by the Biotechnological Engineering students was in their second-year, just prior to the present course. This most likely reflects the importance of becoming accustomed to a new examination method (Kolmos & Holgaard, 2009).

To match expectations between students and examiners, the authors strongly recommend carrying out a trial exam with the students prior to implementing this highly structured oral group examination method. During the trial exam, the skill of rephrasing questions and providing hints instead of answers should be demonstrated and trained with the students. Rephrasing questions and providing hints instead of answers informs the examiners that other students know the answer, but leaves room for the student being questioned, to come up with the right answer. In addition, the authors recommend that the students are trained to raise their hand to indicate a known answer. A simple indication provides time for all students to consider the answer and emphasizes that the exam is not a competition among group members. Moreover, to support a shared focus during the individual examination part, only one individual question should be revealed at a time, which was also explicitly noted by nine students. In practice, this may be orchestrated by letting all students randomly select a number for the examination instead of a question from a pool of questions covering the statistical methods taught during the course. When it is time for the individual student to be examined, the examiner reveals the actual question corresponding to the selected number. Finally, the authors recommend having the same number of students in all groups in order to facilitate an optimal flow during the examination of several groups. Group sizes of three to five are manageable (Billings, 2017). However, the authors prefer four students per group. Four students support group discussions better than three and are easier to manage than five when assessing the performance of each individual student.

In the present study, second year students were randomly assigned into groups, while third year students were self-assigned. It is worth noting that the survey did not reveal any significant difference between second and third year students concerning their level of feeling supported while being examined as a group (Figure 2, Q2). Interestingly, Billings has previously reported that self-assignment into groups positively influences group dynamics (Billings, 2017). No differences in grades were found in the present study between randomly assigned groups (second-year students) and self-assigned groups (third-year students), which was also reported by Nafziger *et al.*, who found no apparent differences in performance between randomly assigned and self-assigned groups (Nafziger, Meseke, & Meseke, 2011).

CONCLUSION

In conclusion, a highly structured oral group examination method was developed and implemented. Thus, an additional method has been added to the toolbox of oral examination methods. The examination method embraces both collaborative and individual assessment that aligns well with courses comprising both collaborative and individual learning and activities. Additionally, the group exam settings do not seem to hinder the students' perception of being able to perform individually. As the results in this study were based on a limited number of students that have tried the oral group examination method only once, it would be of great interest to perform a larger study, including more students, in order to compare and discuss in greater detail the efficacy of different oral examination methods that assess both collaborative and individual learning.

The greatest benefit from changing to the highly structured oral group examination method, however, is the extended examination time, which allows the examiners to assess the students in a more satisfactory manner. In addition, the highly structured oral group examination method provides the opportunity to address higher taxonomic levels of knowledge. As an added bonus, the need for the examiners to ask the same questions repeatedly is greatly reduced. While the highly structured oral group examination method does not require additional time-use per student for the examiners, it does increase the examination time for the students. However, compared with their previous project exams, where students are required to wait while each group member defends their group project individually, the increase in examination time is minimal. Another benefit of the examination method is the included evaluation intermission, which enables the examiners to discuss the performance of each student and adjust the remaining examination accordingly.

Based on the present study, we encourage other educators to explore this highly structured oral group examination method either *de novo* or to develop an existing individual oral examination method further.

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SUPPLEMENTARY MATERIAL

A “ready-to-use" Student Scoring Sheet to ease the task of keeping track of each individual student’s contribution during the examination. (An example is provided in *red*)

Student Scoring Sheet

(A quick and easy way to document the individual student’s contribution during examination)

Group: ______*3*____________

1. Group examination (based on the handed-in report)[1]:

Learning objectives	**Student 1**[2]	***John***	**Student 3**	**Student 4**	**Report notes**
Path of steepest ascent	*2*	*-1*			
Alias structure			*0*	*1*	*0-1?*
....					
....					
Add as many as needed					

2. Individual focus:

	Student 1	**Student 2**	**Student 3**	**Student 4**
	Chosen question 1[2]	*ANOVA*	Chosen question 3	Chosen question 4
Time[3]	Start ____ Finish ____	Start *0:00* Finish *5:59*	Start ____ Finish ____	Start ____ Finish ____
Excellent answers to:		*SST, SSA, SSW*		
Right answers to:		*Assumptions*		
No answers to:		*RE*		
Wrong answers to:		*Two-way*		

3. Group reflection:

	Student 1	**Student 2**	**Student 3**	**Student 4**
Additional contributions or comments?		*Q1: right* *Q2: wrong*		

Notes:

1. To keep track of each student’s contribution during the group examination, a score is given from -1 to 2, where -1 is given for “wrong answer”; 0 for “no answer, 1 for “right answer”, and 2 for “excellent answer”.
2. At the examination, actual student names and chosen questions are recorded on the sheet.
3. Start and finish times are recorded to ensure that each student is examined in the individually allocated time.

BIOGRAPHICAL INFORMATION

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BUILDING STUDENT AGENCY THROUGH ONLINE FORMATIVE QUIZZES

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ABSTRACT

The authors are responsible for a core, first-year module on fluids and thermodynamics for a large class of aerospace, mechanical and product design engineering students. The introduction of a new Virtual Learning Environment (VLE), Canvas, across the university in the 2019/20 academic year, has expanded the potential for active learning and student agency. This paper reports how the curriculum was designed to make use of Canvas features and demonstrates how student engagement was promoted. A key feature of the new curriculum design was a set of formative quizzes spread across the year, each available for a two-week window and with a relatively high pass mark but multiple attempts permitted. No marks were given for the quizzes, but it was necessary to pass them all to be eligible to pass the module. Formative assessments can be an effective strategy to motivate students to build agency, which aligns with section 2.4 of the CDIO syllabus. Quiz 3 was the earliest when not all students passed and two of the three students in question subsequently failed the first summative assessment; this suggests that not only do the quizzes encourage early and consistent engagement with the module, but they also offer the possibility of early identification of students at risk. Evidence of repeated attempts even after a pass mark was achieved suggested a high level of motivation in some students to do well in the quizzes. Student surveys indicated their belief that the quizzes were very helpful. Results from all the summative assessments in the module were significantly improved compared to the previous year, and student satisfaction levels as measured by end of module evaluations were excellent. The outcomes from the redesign have been valuable in informing strategies for the move to effective and engaging online delivery due to the COVID-19 pandemic.

KEYWORDS

Online assessment, quizzes, engagement, student agency, VLE, Standards: 2, 8, 10, 11

INTRODUCTION

Thermodynamics and fluid mechanics modules, frequently taught across a range of engineering disciplines, are often regarded by students as the most challenging subjects in their undergraduate programmes. The challenges in teaching and learning thermodynamics are well documented (Bain et al., 2014; Kesidou & Duit, 1993; Mulop et al., 2012; Rozier & Viennot, 1991; Sokrat et al., 2014; Tatar & Oktay, 2011) and include a lack of prior study at school level, and the conceptual nature of the subject which often leads to a disconnect between theory and practical applications. Similarly, fluid mechanics often has a high level of complexity in the equations presented and therefore requires strong mathematical competency (Alam et al., 2004). Both subjects build incrementally on previous learning and lectures are usually strongly dependent on previous sessions, meaning that missing a few classes can have profound implications on the ability of students to progress through the course (Rahman, 2017).

Similarly, at Queen's University Belfast, students have historically found the first-year Thermodynamics and Fluid Mechanics module to be very challenging, often leading to poor outcomes on the module; for example, in 2018/19 the failure rate was 30%, with a mean score of 51.2%. Problems arise for the students due to being faced with very new content, taught at the outset of their transition to higher education, coupled with large class numbers, typically in excess of 150 students, which limits the student-instructor contact time. An increase in student agency, defined as "*the capacity to set a goal, reflect and act responsibly to effect change…making responsible decisions and choices*" (OECD, 2019) is required to ensure success (Nieminen & Tuohilampi, 2020). This ties closely into the CDIO syllabus, section 2.4 on attitudes, thoughts and learning, which emphasises the importance of engineers taking initiative, responsibility, working independently, and reflecting on and responding to feedback.

The introduction of Canvas as the new VLE for the university in the 2019/20 academic year gave opportunity to introduce measures to provide digitally-enhanced teaching and learning strategies in the module, and encourage active learning, aligning with CDIO standards 8, 10 and 11 on active learning, teaching and assessment, and encourage the building of student agency (Jääskelä et al., 2020). It was of particular interest to ensure continuous engagement of students with the module, and to encourage students to develop independent and self-motivated study skills.

The Use of Online Continuous Assessment

Several studies have shown clear improvements in outcomes through the introduction of continuous online assessment, particularly through the use of quizzes. Nicol (2007) reported on the effect of online multiple choice question (MCQ) quizzes across a number of disciplines and highlighted that while much focus has been previously placed on the limitations of MCQ in testing higher-order cognitive abilities, they can be used to great effect when linked to a specific goal, for example development of learner self-regulation. This links to a previous study (Nicol & MacFarlane-Dick, 2006) which identified seven principles of good feedback which lead to self-regulated learning and student agency (Figure 1).

1. helps clarify what good performance is (goals, criteria, expected standards);
2. facilitates the development of self-assessment (reflection) in learning;
3. delivers high quality information to students about their learning;
4. encourages teacher and peer dialogue around learning;
5. encourages positive motivational beliefs and self-esteem;
6. provides opportunities to close the gap between current and desired performance;
7. provides information to teachers that can be used to help shape teaching.

Figure 1. Principles of good feedback practice (Nicol & MacFarlane-Dick, 2006)

Other researchers continue to demonstrate the benefits of online continuous assessment; for example, Orr and Foster (2013) reported on the introduction of "pre-exam" quizzes as part of a biology course. Results showed that students who took the quizzes tended to score higher on the final exams, and that improvements were seen for students of all abilities who engaged with the quizzes. However, they also reported a significant decrease in completion rate of the quizzes over the course of the module.

Studies by Holmes (2015, 2018) showed that the introduction of low stakes weekly online assessments led to increased engagement with the VLE, and also increased attendance in class. Interestingly, students also reported higher engagement with other module resources, such as increased reading of lecture notes, than in previous years, and the module average increased. Another recent review of methods for online formative assessment demonstrated benefits for students in terms of both module scores and also improved cognitive development (McLaughlin & Yan, 2017). They reviewed the use of quizzes, one-minute papers, e-portfolios and other interactive web-based tools and reported wide ranging benefits across the published studies in terms of final outcomes, engagement, and self-regulation of learning.

The aim of this study was to assess the effect on student engagement and outcomes of the introduction of regular online formative assessment in the first-year thermodynamics and fluid mechanics module in the 2019/20 academic year.

METHODOLOGY

Following a review of the structure and assessment of the module and considering indications in the literature that online quizzes were an effective way of increasing engagement and providing feedback, it was decided to introduce VLE-based formative assessment for the module. This was developed in the form of seven Canvas quizzes spread regularly across the year, each based on the previous 2-3 weeks of lectures. The quizzes were formative and provided no marks, but it was stipulated as a requirement of the module that all quizzes were passed in order for a student to be eligible to pass the module. Due to the issues surrounding the COVID-19 shutdown, and given that the quizzes carried no credit, missed quizzes were waived at the end of the year for the small number of students who failed to complete them all.

Students were given two weeks to complete and achieve a pass mark (generally around 80%) in each quiz, with unlimited attempts. Rather than rely on MCQs alone, the quizzes were set up with a variety of question styles and types to allow assessment of a wide range of levels of learning from simple recall of facts to application of knowledge, to higher analytical skills. Engagement with the quizzes was monitored throughout the year and the outcomes in summative assessments compared with the previous year. Fair comparison over a longer period was difficult due to a relatively large number of staffing and assessment changes in recent years. Some qualitative data was also gathered from students to assess their opinions of the quizzes and the module overall.

RESULTS AND DISCUSSION

Engagement with the quizzes

Table 1 shows that there was excellent student engagement with the quizzes. Quiz 6 showed the lowest percentage pass rate, most likely due to a bunching of submission dates for assignments occurring at that time. Quiz 7 was completed during the first week of the COVID-19 shutdown, and still showed high engagement.

Table 1. Engagement levels with the quizzes

	Module section	Number of students required to take quiz	Number of students who passed	% passed
Quiz 1	Thermo	155	155	100%
Quiz 2	Fluids	155	153	99%
Quiz 3	Thermo	155	151	97%
Quiz 4	Fluids	154	146	95%
Quiz 5	Thermo	153	149	97%
Quiz 6	Fluids	153	134	88%
Quiz 7	Thermo	153	143	93%

Attempts required to pass

Figure 2 shows the number of attempts taken by students to pass the quiz, presented as a cumulative percentage of those attempting the quiz. Quiz 1, given in week 1, was designed to be the easiest quiz and the pass rate was also set lower than subsequent quizzes, at 60%, to ease students into the routine of completing the quizzes. 94% of students passed the quiz on the first attempt and the remaining students passed by attempt 2. Quiz 2, when the pass rate moved to 80%, showed just 40% of students passing on the first attempt, but by attempt 2, 72% of students passed.

Quizzes 2 and 6 showed very similar patterns, with over 90% pass rate by attempt 4. Quizzes 4 and 7 also had similar patterns to each other, in these cases requiring seven attempts for at least 90% of the students to achieve the pass mark. Quiz 5, a quiz on the first law of thermodynamics in closed and open systems, appeared to be the most challenging for students by some distance. It required 13 attempts for at least 90% of the students to reach the pass mark.

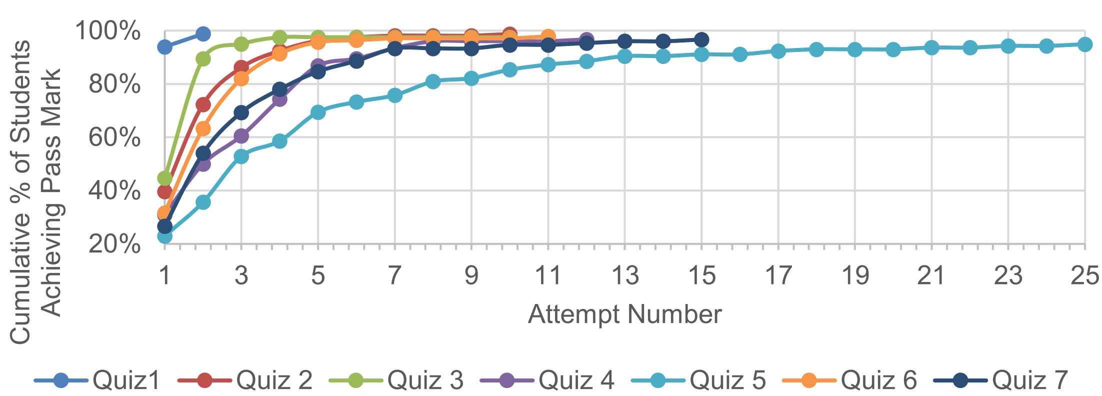

Figure 2. Cumulative percentage of class passing each quiz

Attempts taken by students

The results also showed that many students were motivated to continue to try to improve even after achieving a pass mark, as shown in Figure 3. Fifty students took at least one extra attempt to improve their score on quiz 1, dropping to a low of 17 students in quiz 5, which the students found the most difficult. Quiz 3 showed the highest level of students taking two and three extra attempts to improve their marks. The subject of this quiz was an introduction to using the steam tables, often a challenging topic for students initially, so it may be the case that students were practising using the tables. It is difficult to draw full conclusions on the significance of this as there are several variables that need to be further isolated and analysed in future work, including a benchmarking of the difficulty level of each quiz.

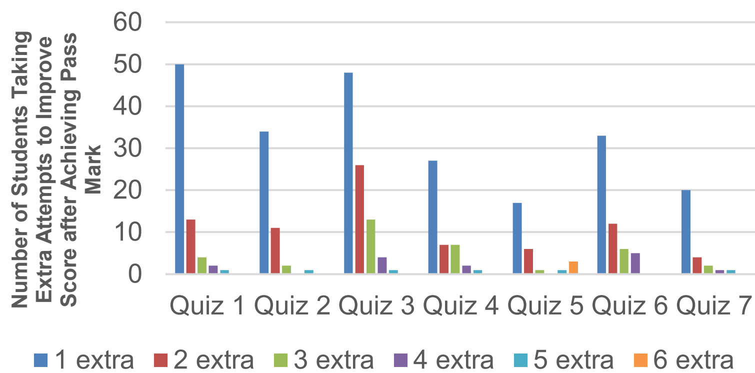

Figure 3. Number of students taking extra attempts to improve score after passing quizzes

Engagement with the Canvas course overall

The quizzes have also increased engagement with the VLE for the module, as seen in Figures 4 and 5, showing much higher page views and participation compared with the other core first-year modules. Canvas participation analytics are generated when a student performs an action such as submitting an assignment, writing a discussion post, or taking a quiz.

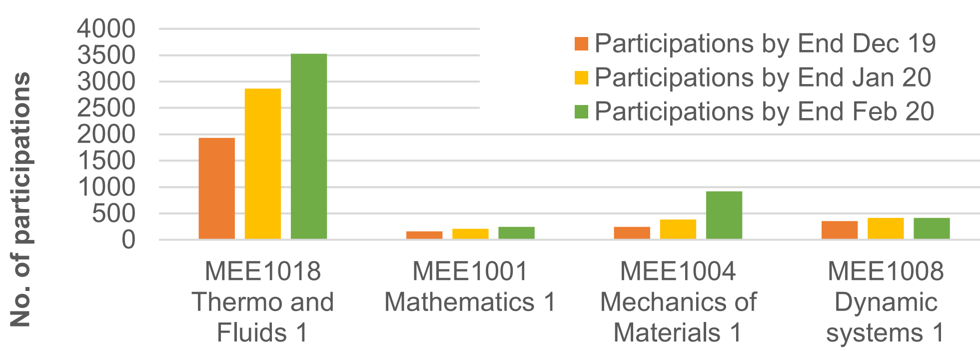

Figure 4. Number of logged “participations” on the first-year Canvas courses

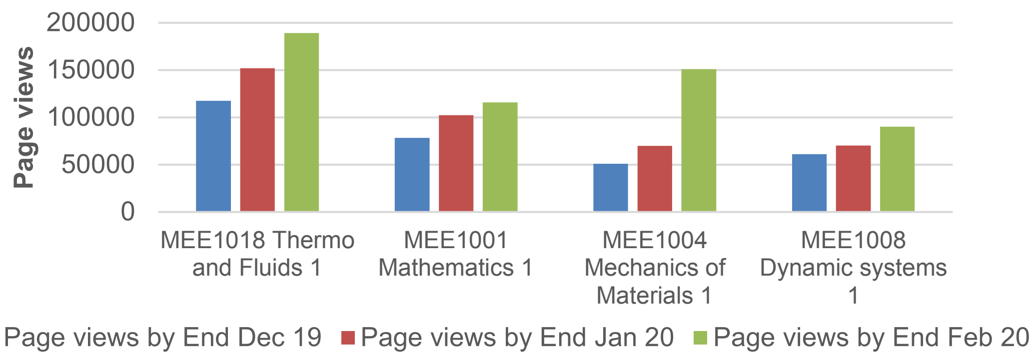

Figure 5. Number of logged “page views” on the first-year Canvas courses

Effect on Summative Assessment

Summative assessment for the module comprised two class tests, one mid-semester 1 and one mid-semester 2, each worth 20% of the module mark, and a final exam worth 60%. The continuous formative quizzes appear to have contributed to improved assessment results. Figures 6 and 7 show the results from students taking each piece of assessment as a first sitting in 2018/19 compared with 2019/20. The averages increased by 16, 11 and 13 percentage points respectively. Two-sample t-tests were carried out to compare the means (table 2), and for each of the three assessments a significant difference was found ($p < 0.001$). It should be noted that the data in Table 2 includes results from a small number of students taking each assessment as a resit, which accounts for the discrepancies in student numbers between Table 1 and Table 2. The percentage of the class who passed each assessment was 20, 25 and 18 percentage points higher respectively.

Caution should be applied before linking improved summative assessment results exclusively to the influence of the quizzes as there was a staffing change on part of the module, and the class tests were not identical in the two years. However, the tests were very similar to the extent that they were of a comparable duration, covered the same range of topics, and were supervised in class in both cases. For the final exam, the COVID-19 shutdown of the university also necessitated an online open-book examination format in 2020. However, the increase in the exam average was in line with the increases in the class tests, so it can be reasonably assumed that the increase on the exam was not solely due to the open-book format in 2020.

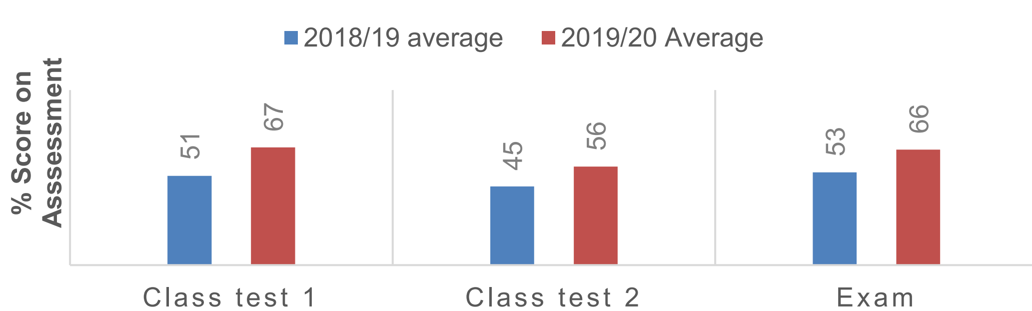

Figure 6. Comparison of average scores in the module’s three assessments

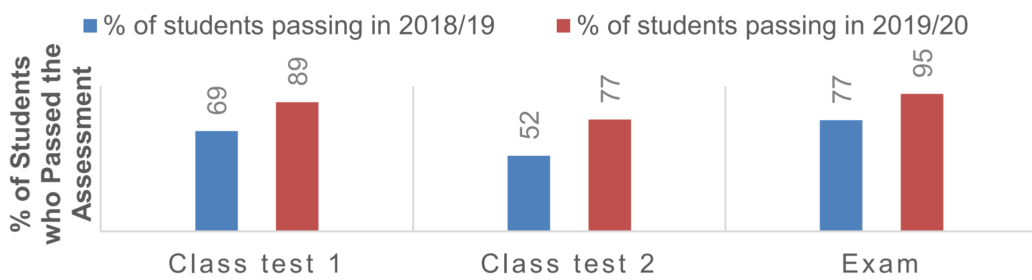

Figure 7. Comparison of percentage of class passing the module's three assessments

Table 2. Comparison of averages for students between 2018/19 and 2019/20 academic years

	2018/19		**2019/20**		**Significant difference in average?**
	Average grade	Number of students	Average grade	Number of students	
Class Test 1	51	158	67	157	Yes, p <0.001
Class Test 2	45	165	56	162	Yes, p <0.001
Exam	53	154	66	158	Yes, p <0.001

Quizzes as a Predictor of Outcomes

The question of whether online formative quizzes and other VLE data can be used to predict outcomes is of great interest. There are numerous studies in the literature which report on student engagement with VLE systems and attempt to link learning analytics with outcomes. Conclusions around these are not always clear and are often contradictory. A review of 252 papers (Viberg et al., 2018) into the effectiveness of using learning analytics found that 35% of the papers showed that learning analytics led to improved learning support and teaching but only 9% provided evidence that student outcomes were improved. More limited value may also be gained from learning analytics in face-to-face courses which are only supported by a VLE, as opposed to fully online courses (Agudo-Peregrina et al., 2014).

In this initial study only a comparison of missed quizzes with outcomes was carried out. It was noted that the first time any students did not complete a quiz was for quiz 3. Out of the three students who did not complete, two failed the first summative class test, held shortly after quiz 3. This suggested at an early stage that quizzes could potentially be used to predict outcomes. At the end of the module the full data was analysed to determine if there was any correlation between missed quizzes and poorer outcomes (table 3). It can be seen that while around 50% of students who failed any of the assessment pieces over the year also missed at least one quiz, it was not always the case that they missed a quiz *before* failing an assessment. It is therefore difficult to determine whether missing a quiz was a predictor of poor performance in an assessment, or if performing poorly in an assessment led to a drop in motivation to engage with the quizzes.

It can however be noted that the average module score for the group of students who missed at least one quiz was 57%; this compares to a module average of 69% for students who passed all quizzes. Much more work is needed to assess the potential for the use of quiz and other VLE data for outcome prediction and early intervention for students at risk.

Table 3: Analysis of the numbers of students failing assessments who also missed quizzes

	Class test 1	Class test 2	Final exam
Number of students who failed assessment	16	28	7
Number of failing students who missed any quiz	8	15	3
Number of failing students who missed a quiz before the assessment	2	8	3
Number of failing students who missed a quiz after the assessment	5	4	N/A
Number of failing students who missed a quiz BOTH before after the assessment	1	3	N/A

Student feedback

Student surveys were carried out at the midpoint of the module to gather general feedback on the module as a whole. Several positive comments were received about the quizzes, including:

- *"Quizzes were quick and helpful; these should be assigned across all modules in the course in my opinion."*
- *"Online quizzes I think are a great way of just checking up on the knowledge from a module."*
- *"Regular, non-graded quizzes in Thermodynamics and Fluid Mechanics module helps to identify an understanding/ lack of understanding of the content being covered."*

The module evaluation questionnaire completed by students at the end of the year showed an increase in the overall satisfaction score from an average of 4.5 out of 5 in 2018/19 to 4.7 out of 5 in 2019/20.

Implications for Online Learning and Assessment, and Further Work

The COVID-19 pandemic has necessitated a switch to online and/or blended learning and assessment in the academic year 2020/21 for many institutions including Queen's University Belfast. This module, along with some other heavily theory-based modules, which are normally taught over a full academic year, has been condensed into one semester, as they are more easily delivered online under current restrictions than more practical modules which will need to take place face-to-face at a later stage when restrictions are eased. This has led to additional challenges both in teaching and assessment planning for the semester. The positive experiences with the quiz format for formative assessment have encouraged the switch to use of the quizzes for combined formative/summative assessment.

However, there were limitations to the previous study which may have implications for the work in 2020/21. For example, very high average scores obtained in the quizzes in 2019/20 mean that some adjustments must be made when using them for summative assessment. Issues with maintaining the integrity and robustness of online assessments are also clear. Benchmarking the difficulties of each quiz is necessary. An assessment of the appropriate type, extent and format of feedback to students is also needed. Results from the experience in 2020/21 will be reported on in due course.

CONCLUSIONS

The introduction of online formative quizzes in a first-year thermodynamics and fluid mechanics module has shown the following:

1. Almost all students displayed a high level of engagement with the quizzes, with an average of 96% completion rate, even when multiple attempts were required to achieve the pass rate. Many students continued to attempt to increase their score even after a pass mark had been achieved, demonstrating high levels of self-motivation. These behaviours concur with the goals outlined in section 2.4 of the CDIO syllabus on attitudes, thoughts and learning.
2. The introduction of the formative quizzes into the module resulted in significantly more engagement with the VLE compared to the other first-year modules, in line with CDIO standard 8 on active learning.
3. A notable increase in the scores for all three summative assessments was seen, and this was accompanied by an increased percentage of students achieving a pass in each assessment piece.
4. An initial analysis of the potential for quiz data to be used to predict outcomes showed some indication of a link between failure to complete one or more quizzes and poorer outcomes in the module. However much more extensive analysis in the area would be needed to draw firm conclusions on this.
5. Feedback indicates that online quizzes are positively received by students and assist them in self-assessment and self-regulation of their learning.
6. The potential for quizzes to be used as combined formative/summative assessment will be trialed in 2020/21, due to the move to online learning, contributing to CDIO standards 10 and 11.

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BIOGRAPHICAL INFORMATION

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UTILIZING GAMIFICATION IN MATHEMATICS COURSES FOR ENGINEERS TO PROMOTE LEARNING

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ABSTRACT

Studies have shown that gamification facilitates students' interest, enjoyment and continuous involvement, allows students to make mistakes anonymously and triggers debates about answers, thus gamification increases students' engagement. In addition, most students respond positively to using online quizzes during the lesson, the main criticism being the short time allowed for each question (Bullón et al., 2018). We examine two aspects of the use of *Kahoot!* online quizzes in three mathematics courses, taught to two groups of first year Israeli engineering students: (1) the effect of using *Kahoot!* quizzes on students' learning outcomes in two questions of the mid-term exams (comparing between traditional teaching and teaching using *Kahoot!* quiz), and (2) students' learning experience. Our findings indicate that in all three courses most of the students did not know how to solve the two questions, neither if the question was taught traditionally nor if it was discussed during the *Kahoot*! lesson. However, in one course (Algebra), students' success was similar in the two groups, which may suggest that using the *Kahoot*! quiz was effective at least as the traditional teaching method. Overall, it is not currently clear whether using the *Kahoot!* quiz has effects on students' achievements. Regarding students' learning experience, our analysis demonstrates that students greatly favor using online quizzes as they feel it deepens their understanding and improves their ability to discuss the taught material. Moreover, the lecturers reported that the use of *Kahoot!* enabled them to review subjects that were taught in the course in an engaging and insightful way, caused a positive change in classroom dynamics and fostered a vivid classroom discussion, addressing issues that otherwise would have remained hidden.

KEYWORDS

Active learning, Gamification, Tertiary Mathematics, Student's engagement, *Kahoot!,* Standards: 2, 8

INTRODUCTION

Students' difficulties with learning tertiary level mathematics have been widely reported in the literature and are related to various aspects such as proving (Alcock & Simpson, 2009), the discrepancy between every-day language and formal-logical language (Epp, 2003) and not understanding how to use definitions (Dickerson & Pitman, 2012). Lithner (2011) discusses the tendency of mathematics teachers to reduce mathematical complexity into inefficient rote learning, and attributes part of this tendency to the attempt to cope with the transition from secondary to tertiary mathematics and the relatively low level of student preparation. Indeed, Selden (2005) reports that there are indications of a decrease in students' knowledge and an increase in negative attitudes towards learning mathematics. Other obstacles in the learning of tertiary mathematics are the fast pace and the frequent encounter with new ways of conceptualizing previously well-known concepts which require students to reconstruct former mathematical knowledge. These obstacles, combined with a constitutional pressure to accept more students into studies that require the use of high-level mathematics (such as Engineering) lead to redesigning first-year mathematics courses in a way that might reduce course requirements (Selden, 2005). In order to try and overcome such learning difficulties Lithner (2011) suggests to better adjust tertiary mathematics education to what he refers to as the new societal assignment (mass education), to conduct more research and to form better connections between research and educational development.

A different line of investigation concerns affective aspects of learning tertiary mathematics. The once sharp distinction between the cognitive and affective domains becomes increasingly blurred, and it is assumed that increasing students' positive affect towards learning will improve their achievements and their learning outcomes. Positive affect of students is related to students' motivation and engagement and to the type of lecturer-students communication that prevails in the classroom. One way of increasing students' engagement is gamification, which we next discuss in the framework of active learning.

ACTIVE LEARNING AND GAMIFICATION IN TERTIARY EDUCATION

Prince (2004) defines active learning as "any instructional method that engages students in the learning process... requires students to do meaningful learning activities and think about what they are doing" (p. 223). Active learning refers to classroom activities that foster students' engagement, in contrast to traditional lectures where students are mostly passive. Assessing the effectiveness of active learning should address a range of outcomes in addition to factual knowledge, such as student skills (e.g., problem solving) and student attitudes. However, such a broad assessment is difficult, since the success of an active learning approach may be open to interpretation, and many learning outcomes are difficult to measure reliably. A renowned example of a pedagogy that employs active learning in large classes is 'Peer Instruction' (PI) (Crouch & Mazur, 2001). PI requires a consistent use of specially designed classroom tasks, pre-lesson reading materials, appropriate assessment methods and meticulous lesson design. Crouch and Mazur establish the high positive influence of using PI in Physics course on students' achievements, especially regarding conceptual reasoning and quantitative problem solving. Cronhjort et al. (2013) reported that the use of PI in a calculus course for beginning engineering students helped students achieve better results in exams and that students felt motivated and appreciated being more active. However, students also found the method challenging and somewhat frustrating, partly because of difficulties related to the pre-lesson textbook reading. Michael (2006) describes educational case studies in several science courses and concludes that clearly "… there are large bodies of evidence from a number of different fields supporting the effectiveness of active learning" (p. 164). Prince (2004) and Michael (2006) claim that such supporting evidence should encourage faculty to consider nontraditional ways of teaching. Indeed, Peters and Prince (2019) used open-ended, ill-formed problems as means to enhance first-year undergraduate students' higher order thinking skills and complement the competencies students developed through an active learning model.

Gamification is an active learning approach, used to increase students' engagement and motivation in the classroom, and its influence in higher education is constantly growing (Holmes & Gee, 2016; Subhash & Cudney, 2018). According to Holmes and Gee (2016) the recent growing use of games in tertiary education could be an outcome of the attempt to appropriately utilize affordances of new digital technologies to enhance innovative teaching and learning. Subhash and Cudney (2018) offer a vast literature review aimed to identify beneficial components of gamified learning in order to detect contexts in higher education in which gamified learning systems are effectively implemented. They observed that a number of studies demonstrated that gamified learning could be effective in the science studies. Improved student motivation and enjoyment, engagement, and performance were widely reported as the most significant benefits of gamified learning in higher education. Student attitudes (e.g., participation, confidence, interest) were also an important benefit (Bullón et al., 2018; Subhash & Cudney, 2018). The use of achievements and status marks (e.g., bonus points) were among the most frequently used game elements and were identified both as important and suitable for use in higher education. Instant feedback was also an apparently important feature (Subhash & Cudney, 2018). Holmes and Gee (2016) note that nowadays many educators complain about students not being engaged in the lesson, and gamification is a way of "revitalizing education and replacing old, outdated teaching methods with activities and techniques more closely aligned with the expectations and interests of modern, tech-savvy students" (p. 9). The review of Subhash and Cudney (2018) found overwhelming support for other benefits in higher education, such as improved learning outcomes, reduced failure rates and higher average scores (although not necessarily in the final exam scores). Subhash and Cudney recommend further research on gamified learning in engineering disciplines.

In spite of the mentioned benefits, gamification is also criticized by some educators, who perceive gamification as a "re-skinning" of a classroom and not as a real innovation. Others feel that gamification risks implementing play features in meaningless ways, that gamified activities are applied in inappropriate places or that gamification focuses more on "playing" than on deep learning. These critics worry that gamification might cover up for bad course design or bad learning objectives (Holmes & Gee, 2016). Hence one should examine gamification approaches in light of their potential to promote teaching and provide learning opportunities.

For Perdue (2016), the use of games in tertiary level mathematics courses effectively harnesses the time and energy of the students to learn mathematical subjects in enjoyable ways, motivating and engaging them while still allowing them a certain degree of control and autonomy. Perdue tackles the question "How do we want our students to *feel* when they are in class, engaged in solving a math problem, and learning?" (p. 152) and claims that the design of the mathematical task should incorporate a clear quest, a significant reward, choices, unexpectedness and ownership. One way to incorporate such elements in a classroom task is by using a gamification application like *Kahoot!,* which is a game-based online platform designed for social learning. It consists of quizzes of multiple-choice questions and is played by the participants simultaneously and individually via a common screen, web browser and mobile phones, tablets or laptops. When used in classrooms, the teacher prepares quizzes in advance and controls the quiz pace by setting a maximum time for each question. During the quiz all players connect (possibly anonymously) using a generated game PIN. The application does not reveal the right answer and does not continue to the next question until all the students answered a question or time runs out. After each question, *Kahoot!* assigns each student a score that depends both on the answer's correctness and the time invested in it. After all students answer a question, each student receives personal feedback and the PIN of the current leading student. At the end of the quiz, results can be downloaded by the lecturer (Bullón et al., 2018).

Studies on using online tools have shown advantages such as allowing students to make mistakes anonymously and triggering debates about (in)correct answers. Most students respond positively to the use of online quizzes during the lesson, the main criticism being the short time allowed for each question in the quiz (Bullón et al., 2018). Perdue (2016) reports that she has "…witnessed the power of *Kahoot!* to transform a class of lifeless… students into an excited, energized, motivated group of people competing for mastery of a topic" (p. 153) and recommends the use of *Kahoot!* as a first experience in gamification for lecturers.

Bullón et al. (2018) used *Kahoot!* quizzes in a discrete mathematics course and concluded that most students favor the use of *Kahoot!*, possibly because of the lack of grading. The main students' criticism related to the competition mode and the time allowed for each question. They further claimed that using *Kahoot!* (or a similar online application) enabled lecturers to trigger student participation, for students were asked (but not forced) to respond. In addition, they claimed that it encourages students to think and reflect. Licorish et al. (2018) interviewed fourteen university students about the influence of *Kahoot!* on classroom dynamics, students' engagement, motivation and learning and found that it: (1) increased students' focus by creating breaks that helped to sustain attention, and (2) provided students opportunities to interact with the lecturer, peers and lecture content in a fun way. In their study, the students noted that the competitive aspect increased their motivation, the anonymity encouraged participation, and that the use of *Kahoot!* increased their knowledge and overall was a valuable and enjoyable learning aid. The last aspect, enjoyment, possibly underlies the former positive aspects. Licorish et al. (2018) remark that due to the small number of participants in their study (14) a larger scale follow-up is recommended.

In this paper, we present findings from a study in which online *Kahoot!* quizzes were used in three mathematics courses taken by first year Engineering students, in order to increase students' engagement, allow lecturers to discuss mathematical concepts in a deep and interesting way and enable the incorporation of high-level questions in the mid-term exam. We present findings concerning students' achievements and learning experience.

RESEARCH QUESTIONS

The goal of this research was to study the effect of using *Kahoot!* online quizzes in tertiary mathematics courses taken by first year engineering students. In particular, we wished to learn:

1. The effect of using *Kahoot!* quizzes on students' achievements in the mid-term exams;
2. The effect of using *Kahoot!* quizzes on students' learning experience.

METHODOLOGY

1. Research setting and population

The study was conducted in three mathematics courses: discrete mathematics, linear algebra and multivariable calculus, taken by first year students in an Engineering college in Israel. Each course was taught by a different lecturer to two different groups of students (20-50 students in each group). In each course, the lecturers used a *Kahoot!* online quiz (50 minutes) during a lecture. The lecturers are all experienced, with over 10 years of experience, teaching mathematics to engineering and mathematics students in universities and colleges in Israel.

2. Experimental design: Kahoot! lesson and mid-term exam

We designed a 50 minutes lesson activity of a *Kahoot!* quiz in two courses: discrete mathematics, linear algebra). The activity had two main goals: (1) A mid-term summary of the course; (2) Acquaintance with new high-level questions that were planned to be included in the mid-term exam. Each course was taught to two groups of students. In those courses the mid-term exam included two questions that were taught as follows: in Group 1, Question X was discussed during the *Kahoot!* lesson and Question Y was taught in a traditional frontal lesson, and in Group 2 the opposite. In addition, we performed a short *Kahoot!* activity which included only one question, a different one for each group in a multivariable calculus course. The questions were not taught in a traditional frontal lesson. We describe in details the design of the questions in discrete mathematics course and provide a brief description of the design in the two other courses (for more details see Appendix A).

Discrete Mathematics studies discrete mathematical structures and includes topics from logic, set theory, combinatorics and graph theory. The *Kahoot!* activity included 16 questions. The two questions were (correct answer highlighted in green):

Question X: Let *A* be a set of 5 elements. What is the number of all possible relations above *A*?

a. 25   b. 2^5 c. 2^{25} d. $(2 \cdot 5)^5$

Question Y: Let *R* be an equivalence relation over a set *A*. Then, necessarily there is a function *f: A → R* which is:

a. injective   b. surjective   c. inverse   d. all the answers are correct

Both questions require an understanding of definitions of set theory concepts, connecting definitions of concepts that do not explicitly appear in the question. For example, Question X requires linking the concepts 'relation' and 'a power set' (the latter is not explicitly mentioned). The student must apply the two arguments: a relation above a set *A* is a subset of *A*×*A*; the number of elements in the power set of a set *B* is 2^n, where *n* is the number of elements in *B*.

Linear algebra studies linear systems of equations, vector spaces, and linear transformations. The *Kahoot!* activity included 14 questions. Questions X-Y in this course were aimed to check the students' theoretical background about the connection between a matrix, its properties (e.g. rank) and linear equations. An immediate goal was to check if the students can determine the number of solutions to the corresponding system of linear equations just by observing a matrix, without performing calculations. Other goals were explicating the relation between the rank or determinant of a matrix and the number of solutions. A more general aim was to examine if students would be able to use a specific mathematical tool in more than one way, and to show them it is possible. The multivariable calculus course studies differential, integral and vector calculus for multivariable functions. The *Kahoot!* activity included the study of questions about tangent plane and rate of change of differentiable functions. One of the goals of the activity was to verify if the students master the exact definitions. Furthermore, we were interested in applying the theory presented in the course in an unfamiliar context, trying to determine to what extent engineering students can translate an abstract mathematical concept to a real-world problem.

3. Students' Feedback Design

After the *Kahoot!* lessons in discrete mathematics and linear algebra we administered students' feedback questionnaires (based on Bullón et al., 2018) regarding students' learning experience. We consider all answered questionnaires as one set of data, since they do not relate to mathematical content. We present the relevant questions (Q3-Q4):

Q3: Please refer to the following statements and choose the evaluation which best expresses your opinion: *(1) very favorably; (2) somewhat favorably; (3) indifferent; (4) somewhat unfavorably; (5) very unfavorably*.
How do you value the use of:
- Q3.1 technologies (tablets, mobile phones, etc.) for teaching and learning in class?
- Q3.2 *Kahoot!* to develop analytics and decision making related to the taught material?
- Q3.3 *Kahoot!* to expand knowledge and/or deepen understanding of the taught material?
- Q3.4 *Kahoot!* as motivating the relevance of the topic?
- Q3.5 *Kahoot!* as a way to ensure your classroom attendance?
- Q3.6 *Kahoot!* to increase satisfaction with the teaching and learning of the taught material
- Q3.7 *Kahoot!* in lessons in general?

Q4. Please comment on the use of the *Kahoot!* quiz in the lesson (an open question).
Students' answers to Q4 were collected. Repetitive answers were coded according to six themes that emerged from the data (see Table 10 in Section 5.2).

FINDINGS

1. Students' answers to Kahoot! quizzes and achievements in mid-term exams

1.1 Discrete mathematics course

<u>*Kahoot!* answers</u>

Table 1 presents the overall students' achievements in the *kahoot!* quiz in discrete Mathematics course. Table 2 presents the findings for Questions X-Y. The correct answer is shaded in green.

Table 2 demonstrates the low success rate of the students in the two groups in solving Questions X and Y. In both classes a detailed explanation of how to solve the questions was given. This exemplifies how the use of the *Kahoot!* activity enabled teaching new implantation and connections of math concepts in an innovative an engaging way.

Table 1. Students' achievements in *Kahoot!* quiz - Discrete mathematics (16 questions)

Discrete Mathematics	Group 1 (N=13 students)	Group 2 (N=12 students)
Total correct answers (%)	35.03%	35.64%

Table 2. Discrete mathematics – Students' answers to Questions X-Y (Allowed time: 60 [sec])

Group 1 (N=13), Question X	(a) 4 (30.7%)	(b) 8 (61.5%)	(c) 0 (0%)	(d) 0 (0%)
Group 2 (N=12), Question Y	(a) 1 (8.3%)	(b) 3 (25%)	(c) 2 (16.7%)	(d) 6 (50%)

Mid-term exam achievements

Table 3 summarizes the mid-term exam achievements. The students were considered as successfully answering the question if their question grade was ≥70. The findings indicate that in Group 1 the success rates were significantly higher for the question that was solved in a traditional lesson, whereas in Group 2 there was no difference.

Table 3. The results in the mid-term exam in Discrete mathematics, Questions X and Y

	Group 1	Group 2
Number of students with grade ≥70 - Question X	1 of 18 (Traditional)	2 of 25 (*Kahoot!*)
Number of students with grade ≥70 - Question Y	7 of 18 (*Kahoot!*)	2 of 25 (Traditional)

1.2 Linear Algebra Course

Kahoot! answers

Table 4 shows the overall achievements in the *Kahoot!* quiz in linear algebra course. Table 5 presents the results for Questions X-Y. The correct answer is shaded in green.

Table 4. Overall Performance in *Kahoot!* quiz for linear algebra (14 questions)

Linear algebra	Group 1 (N=24 students)	Group 2 (N=32 students)
Total correct answers (%)	46.73%	52.9%

Table 5. Linear algebra – Students' answers to Questions X-Y (Allowed time: 120 [sec])

Group 1 (N=24), Question X	(a) 3 (12.5%)	(b) 4 (16.7%)	(c) 8 (33.3%)	(d) 8 (33.3%)
Group 2 (N=32), Question Y	(a) 3 (9.4%)	(b) 5 (15.6%)	(c) 7 (21.9%)	(d) 15 (46.9%)

Mid-term exam achievements

Table 6 presents a summary of the mid-term exam achievements. In both groups, most of the students were not able to get full credit for the two questions. Furthermore, there is no evidence of a significant difference between students' success in each question and in each group when taught via Kahoot! or via a traditional frontal manner.

Table 6. The results in the mid-term exam in linear algebra, Questions X and Y

	Group 1	Group 2
Number of students with grade ≥70 - Question X	1 of 45 (Traditional)	3 of 28 (*Kahoot!*)
Number of students with grade ≥70 - Question Y	4 of 45 (*Kahoot!*)	7 of 28 (Traditional)

1.3 Multivariable Calculus Course

Kahoot! answers

In this course the *Kahoot!* quiz included only one question, a different question for each group. Table 7 summaries the results for Questions X-Y. The correct answer is shaded in green.

Table 7. Multivariable calculus – Students' answers to Questions X-Y (Allowed time: 90 [sec])

Group 1 (N=26), Question X	(a)13 (50%)	(b) 4 (15.4%)	(c) 7 (26.9%)	(d) 2 (7.7%)
Group 2 (N=21), Question Y	(a) 10 (47.6%)	(b) 6 (28.6%)	(c) 3 (14.3%)	(d) 2 (9.5%)

Mid-term exam achievements

Table 8 presents a summary of the mid-term exam achievements. In both groups only the best students answered the question satisfactorily. This may suggest that students who answered the question correctly in the *Kahoot!* probably answered it correctly in the exam as well.

Table 8. The results in the mid-term exam in multivariable calculus, Questions X and Y

	Group 1 – Question X	Group 2 – Question Y
Number of students with question grade ≥70	8 of 35 (*Kahoot!*)	6 of 43 (*Kahoot!*)

2. Students' feedback

The post lesson questionnaire was answered by 51 students. Table 9 presents findings from students' questionnaires. The most frequent answer is shaded. Twenty-four (24) students answered the open question (Q4) about the use of *Kahoot!* quiz in lessons. Table 10 presents our findings, according to the different aspects we defined.

Table 9. Findings from students' questionnaires

	Q3.1	Q3.2	Q3.3	Q3.4	Q3.5	Q3.6	Q3.7
(1) Very favorably	49%	37%	32%	39%	39%	41%	41%
(2) Somewhat favorably	41%	37%	46%	27%	37%	49%	41%
(3) Indifferent	6%	14%	14%	24%	10%	6%	10%
(4) Somewhat unfavorably	4%	10%	6%	6%	6%	0%	6%
(5) Very unfavorably	0%	2%	2%	4%	8%	4%	2%

Table 10. Findings from students' answers to Q4 in the questionnaire

Aspects	*Themes that emerged in students' answers*
1. General description of the experience	A good way to summarize material, breaks routine, fun, refreshing.
2. Class atmosphere	Creates positive atmosphere in class
3. Insights about the learning process	It motivates learning at class and at home It helps prioritizing learning and on which topics to focus Lessons learned from mistakes, sharpens a number of inherent emphases on the subject.
4. Students' requests and suggestions	To announce in advance that the next lesson will be a Kahoot! quiz and on what subject, so students can prepare in advance. To publish a complete and formal solution of the answers.
5. Influence of elements of gamification	Competitiveness improves learning The time limitation is stressful

6. Using Kahoot! to learn mathematics	Less relevant for practicing proofs and a formal way of writing a full solution

We present two students’ quotes that demonstrate aspects 1,2,3,5 in Table 10:

- "In my opinion the use of *Kahoot!* is very refreshing and positive, creates a different and uplifting atmosphere, in addition sharpens a number of understandable emphases on the subject, but with the transparency of the results should be limited, the dimension of time is very influential when solving the exercises and thinking about them".
- "Competitiveness improves, and it's also more fun. In addition, if you come out as bad as I did last time, it only spurred me on to come home and sit down to learn more because I wasn't happy with the outcome. I am in love with the idea of finishing a topic and doing some kind of *Kahoot!* quiz on the topic".

DISCUSSION

The findings in Section 5.1 indicate that the use of *Kahoot!* quizzes did not have a positive effect nor a negative effect on students’ achievements in the mid-term exam in any of the three courses. Considering the lecturers utilized the *Kahoot!* quizzes not only to summarize and repeat previously taught mathematical content but also as a way to introduce non-routine and advanced questions to the students, and that one of the experimenting lecturers reported that the use of the *Kahoot!* quiz was less time consuming than discussing the same content in a traditional frontal lecture, it seems that teaching via *Kahoot!* is at least as effective as the traditional frontal manner. However, it seems that teaching with *Kahoot!* has other advantages, for example it promotes mathematics teaching that encourages less procedural or algorithmic mathematical thinking, as advised by Lithner (2011). One possible explanation for the lack of positive effect of the *Kahoot!* activity on students’ achievements is that the lecturers reported that students treated this activity as “a game”, and did not take notes even though important explanations were constantly given by the lecturers throughout the activity. This corresponds to the criticism of Holmes and Gee (2016) that gamification does not necessarily serves learning and that gamification focuses more on “playing the game” than on deep learning. Another possible explanation is that the effect of a single gamified activity is perhaps unable to create a substantial change, as Crouch and Mazur (2001) state: “students often require a period of adjustment to new methods of instruction before their learning improves” (p. 974). So, it is possibly necessary that the lecturer use *Kahoot!* quizzes consistently and thus establish an appropriate classroom culture and norms that will enable the effective use of these quizzes. Thus, we conclude that the use of the *Kahoot!* quiz is indeed an innovative way of triggering deep mathematical discussions in the mathematics classroom in tertiary level, providing that the lecturers who use it succeed in creating an appropriate students’ attitude and norms during lessons where these online quizzes are used. This is a matter for future research.

More advantages of using *Kahoot!* quizzes are demonstrated in the findings in Section 5.2. It seems that students clearly favored the use of *Kahoot!* quizzes as a way to develop analytical thinking and decision-making skills, expand their knowledge and deepen their understanding. Moreover, students stated that the use of *Kahoot!* quizzes encouraged them to attend the lesson, increased their motivation and enjoyment and is overall a satisfactory experience. Therefore, we conclude that the use of *Kahoot!* has a positive effect on the learning experience of students, and on their motivation, enjoyment and engagement, in agreement with the current literature. (Licorish et al., 2018; Subhash & Cudney, 2018). However, in contrast to the report of Subhash and Cudney (2018), we did not detect positive effects on students’ performances, failure rates or scores. Concerning the “allowed question time”, our findings (Table 10) agree with Bullón et al. (2018), that some students find the time limitation in *Kahoot!* Stressful. Yet, our *Kahoot!* data indicate that students’ average answering time was less than the time limitation for each question; this phenomenon may be of interest for further investigation (for example, one may investigate if cancelling the time limitations effects students’ success).

The different aspects that were raised by the students (Table 10) explain various characteristics of their positive learning experience and offer important insights. One interesting suggestion that was raised by the students is to announce in advance that a *Kahoot!* activity will take place so that students will be able to prepare themselves to the lesson. This suggestion indicates that the students possibly recognize the potential of the *Kahoot!* activity as a learning aid, and wish to make a better use of its offerings. A second interesting student observation is that the *Kahoot!* activity is less relevant for learning proofs and practicing the formal way of writing a full solution to a problem. This observation motivates a future research direction, examining what type of mathematical content, methods and techniques are best supported by the use of *Kahoot!*. As Selden (2005) stated: “The mathematical community should surely keep ‘what works’… while responding to new pedagogical challenges and technological tools, and change what doesn’t work. So, mathematics education researchers, together with mathematicians, need to ask themselves, what works and why? …[the] technology will change. Whether mathematics professors and teachers will use changes in technology wisely remains to be seen” (p. 144).

Finally, we wish to briefly address the challenge of promoting students’ engagement in online courses, which during the COVID-19 pandemic became the prevailing teaching format in tertiary education. Research shows that online instruction is most effective when it requires active student cooperation and utilizes collaborative activities (e.g., group discussions), and when it includes a strong instructor presence, i.e. when the instructor is actively involved in the learning process of the students, preferably in varied ways (Dixon, 2010). Betts (2009) claims that it is important that lecturers integrate effective communication strategies into online course design and instruction if they wish to engage students in learning. However, many students and researchers comment that distance learning courses lack interaction. We suggest that using online platforms such as *Kahoot!* is a convenient and effective way to foster various types of interactions (lecturer-student, student-student and student-content) and group activities, thus engage students in learning during a synchronous online lesson. Since online courses are becoming more and more prevalent, we recommend future research concerning the effects of using *Kahoot!* in online lessons.

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APPENDIX A

Linear algebra – Questions X-Y

The *Kahoot!* quiz included 14 questions. The correct answers to Questions X-Y are highlighted in green.

Question X: Given that $Adj(A)=\begin{pmatrix}1&0&4\\2&0&8\\7&9&-2\end{pmatrix}$, and denote $A=\begin{pmatrix}a_{11}&a_{12}&a_{13}\\a_{21}&a_{22}&a_{23}\\a_{31}&a_{32}&a_{33}\end{pmatrix}$.

For which matrix B, does the equation $Bx=0$, has infinite number of solutions?

a. $B=\begin{pmatrix}a_{21}&a_{23}\\a_{31}&a_{33}\end{pmatrix}$

b. $B=\begin{pmatrix}a_{11}&a_{13}\\a_{31}&a_{33}\end{pmatrix}^T=\begin{pmatrix}a_{11}&a_{31}\\a_{13}&a_{33}\end{pmatrix}$

c. $B=A$

d. none of the above

Question Y: The matrix $\begin{pmatrix}a_{11}&a_{12}&a_{13}&a_{14}&a_{15}\\a_{21}&a_{22}&a_{23}&a_{24}&a_{25}\\a_{31}&a_{32}&a_{33}&a_{34}&a_{35}\end{pmatrix}$ is row equivalent to $\begin{pmatrix}1&2&0&3&0\\0&0&4&-1&0\\0&0&0&0&5\end{pmatrix}$.

For which of the given systems, one does not know how many solutions exist?

a. $\begin{pmatrix}a_{11}&a_{12}&a_{13}&a_{14}\\a_{21}&a_{22}&a_{23}&a_{24}\\a_{31}&a_{32}&a_{33}&a_{34}\end{pmatrix}\begin{pmatrix}x_1\\x_2\\x_3\end{pmatrix}=\begin{pmatrix}a_{15}\\a_{25}\\a_{35}\end{pmatrix}$

b $\begin{pmatrix}a_{11}&a_{12}&a_{13}\\a_{21}&a_{22}&a_{23}\\a_{31}&a_{32}&a_{33}\end{pmatrix}\begin{pmatrix}x_1\\x_2\\x_3\end{pmatrix}=\begin{pmatrix}a_{14}\\a_{24}\\a_{34}\end{pmatrix}$

c. $\begin{pmatrix}a_{11}&a_{12}&a_{13}\\a_{21}&a_{22}&a_{23}\\a_{31}&a_{32}&a_{33}\end{pmatrix}\begin{pmatrix}x_1\\x_2\\x_3\end{pmatrix}=\begin{pmatrix}3\\-1\\0\end{pmatrix}$

d. $\begin{pmatrix}a_{11}&a_{13}&a_{15}\\a_{21}&a_{23}&a_{25}\\a_{31}&a_{33}&a_{35}\end{pmatrix}\begin{pmatrix}x_1\\x_2\\x_3\end{pmatrix}=\begin{pmatrix}0\\0\\0\end{pmatrix}$

Multivariable calculus – Questions X-Y

The correct answers to Questions X-Y are highlighted in green.

Question X: The function *f:* $\boldsymbol{R}^2\rightarrow\boldsymbol{R}$, *z=f(x,y)* is differentiable. The tangent plane to the graph of *f* at (0, 0) is given by the equation: *6x+8y+z=0*. Find the instantaneous rate of change of *f* in the direction of the unit vector ***u*** = *(0.6, 0.8)*.

a. $(-6)\cdot 0.6+(-8)\cdot 0.8=-1$

b. $|-6|\cdot 6+|-8|\cdot 8=100$

c. $(-8)\cdot 0.6+(-6)\cdot 0.8=-0.96$

d. $0.6:|-6|+0.8:|-8|=0.2$

Question Y: The length of a rectangle is increasing at a rate of 3 [m/sec] while its width is increasing at a rate of 2 [m/sec]. At what rate, in [m^2/sec], is the area of the rectangle changing when its length is 15 meters and its width is 6 meters?

a. 15·3 + 6·2 = 57 [m^2/s]

b. 15+3·2=15+6 =21 [m^2/s]

c. 6·3+15·2=48 [m^2/s]

d. Cannot be answered, there are missing inputs.

Remark: It seems that Question Y is discussed at numerous open online websites such as: Study.com, Quora, Math.stackexchange, Enotes, Socratic.org or Numerade.

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STUDENTS' PERCEPTIONS OF MULTICULTURAL GROUP WORK IN INTERNATIONAL ENGINEERING CLASSROOM

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ABSTRACT

The rapid internationalization of engineering leads universities to change their education in ways that meet diverse students' learning needs. The ambition behind the internationalization policy at Eindhoven University of Technology (TU/e) is that the multicultural experiences will improve the quality of educational experiences for all students. In a small-scale interview study, we explored how domestic and international students perceived the challenges and gains in their multicultural student group work experiences in master programs at TU/e. In addition, the factors that influence multicultural group work were explored based on students' experiences. Key challenges that were identified are different communication styles and language issues, whereas key gains are mainly related to complementary knowledge and skills for domestic and international group members. In the group process, factors in which they were similar were found, for example both domestic and international students preferred to work with someone they already know. Difference in students' perceptions of group work behaviors, such as division of task and disagreement solution were found between domestic and international interviewees. The factor of culture seems to play a role in interpreting the above differences. Based on the results, we concluded that the vision of an international classroom has not yet been achieved. The results suggest that inclusion at the university still needs to be taken a step further, and this paper provides a basis for discussion on how to move the vision forward.

KEYWORDS

Diversity, Cross-cultural collaboration, Multicultural student group, Standards: 2, 3, 7, 8.

INTRODUCTION

Eindhoven University of Technology has been striving for internationalization as part of the 2030 education strategy (TU/e, 2018). To achieve internationalization, "international classroom" was recently defined as a learning space of a group of students in which: 1) different nationalities with different cultures are present, 2) the common instruction language is English, 3) students and staff engage in and appreciate multicultural teams, and 4) the diverse learning environment is (created) such that it enables students to gain multicultural experiences and enhances the education quality. The above definition clearly indicated two main goals behind the establishment of the international classroom at the university.

A first goal is to enable students to engage in multicultural teams and gain multicultural experiences. There are currently a lot of courses that involve different types of group assignments and projects at the university. All these group assignments indeed create opportunities for students to work in multicultural groups. The lack of interaction between domestic and international students in a group project has become a common concern in most English-speaking countries, such as the US and UK (Arkoudis et al., 2013). In response to this, there has been good initiatives to facilitate multicultural interactions, such as the examples that have been presented at CDIO conferences: improved introductions to Master programs for international students (Knutson Wedel & Persson, 2010), intercultural training for students (Josefsson, 2010), cross-cultural training for teachers (Van Puffelen & Van Oppen, 2020), well-organized intercultural social activity for students (Gourvès-Hayward et al., 2013), and integrated group work (Bergman et al., 2017). Challenges of working in a multicultural student group have been reported to comprise language barriers, academic culture differences, and a negative experience with and/or a stereotype view of international students (Safipour et al., 2017). In the Netherlands, this could be even more complex since English is not the native language for both Dutch and (most) international students. Thus, it is worthwhile to explore the challenges and gains that Dutch and international students perceive in their multicultural group work experiences, to create a better diverse learning environment at the university.

A second goal of the international classroom is to enhance the quality of education. It means that all students are expected to gain positive outcomes from their multicultural group work experiences. Both domestic and international students need and learn skills of diverse teamwork and intercultural communication (see CDIO syllabus items 2.4.2, 2.5.2, 2.5.5, 3.1.1, 3.2.2, 3.2.10, and 4.1.6). Research showed no consistent finding of the diversity effect on either group performance or group cohesion (Webber & Donahue, 2001). Members of multicultural groups, compared with homogeneous group members, are found to encounter more challenges in the group process due to misunderstandings and coordination difficulties when working together (Popov et al., 2019). In the education context, multicultural student groups can have very promising as well as very disappointing education outcomes. Thus, it is the question of what factors facilitate or hinder the multicultural student group work in the international classroom at TU/e.

THEORETICAL FRAMEWORK

Marks et al. (2001) provided an integrated model of input-process-output (I-P-O), which helps to understand the key variables or processes that are embedded in team collaborative learning. Their argument is that team outcome is not only influenced by the team input, such as team members' talents, but also (and perhaps more importantly) by the processes team members use to collaborate with each other to accomplish the work.

The *input* refers to the composition of a team, including individual characteristics such as competency and personality, and team level attributes such as task structure and external leader influences (the role of the teacher) (Mathieu et al., 2008).

The *process* refers to the activities that team members engage in to resolve the task demands and learning. These activities were further distinguished into transition process, action process, and interpersonal process. The transition process refers to group planning activities, including task analysis and planning, goal specification, and strategy formulation. The action process refers to group collaboration activities, including monitoring progress towards goal accomplishment, team monitoring and backup behaviour, and coordination of the interdependent tasks. The interpersonal process refers to group regulation activities, including conflict management, motivation and confidence building, and affect management such as emotion regulation.

The *output* refers to: 1) performance judged by relevant others external to the team (e.g., teacher), b) meeting of team-member needs, and 3) willingness of members to remain in the team.

RESEARCH QUESTIONS

This study is a small-scale explorative study aimed at descripting students' perceptions of their multicultural student group work experiences in the current international classroom at the university. Given the above research aim, three research questions were formulated:

1) What challenges and gains do domestic and international students perceive from their multicultural student group work?

2) What cultural differences do domestic and international students perceive from their multicultural group work?

3) What factors that influence multicultural group work can be found from students' experiences?

RESEARCH METHOD

This study was approved by the Ethical Review Board of the university <ERB2020ESEO5>. Ten individual Skype interviews were conducted, in English, between February and April 2020. The interviews lasted between 34 to 60 minutes with an average of 52.

Currently, about 21% of the master students at the university are international students, comprising students from European countries (EER) (roughly 2/3) and non-European countries (non-EER) (roughly 1/3) (Taconis et al., 2020). Ten master students from different programs that consisted of a substantial number of group work elements and had a relatively high number of international students participated. The interviewees included five Dutch students and five internationals (one Portuguese, one Pakistani, and three Chinese). Nine of the interviewees were second-year master students and one was a first-year master student. All ten interviewees had experienced group work quite often, such as almost every course or at least once per quarter.

A semi-structured interview was constructed including three main sections. The first section consisted of questions about participants' backgrounds such as their nationality and frequency of their multicultural group work experiences. The second section included questions about their recent multicultural group work experiences. In this section, we asked interviewees to pick up one successful example from their multicultural group work experiences and explained the reason for success. After that, we structured questions based on the input-process-output (IPO) model to elicit the variables/processes influencing their group work. For example, we asked interviewees *how do they form their group*, *how do they divide the workload*, and *how do they share information*. The third section included questions about students' perceptions of challenges and gains from working in multicultural student groups.

A try-out interview was conducted to verify whether the interview questions were understandable and would result in rich answers, and to test the duration of the interview. This resulted in minor reformulations of the wording of the questions and the formulation of suitable follow-up questions.

Interviews were transcribed and analysed using open coding (Blair, 2015) with the aid of Atlas.ti program. The data collection and data analysis were conducted in parallel, and the data analysis consisted of the following three steps. Firstly, we open coded the transcription based on reading it line by line. A code was assigned to a text fragment, which represents its meaning. A list of codes was generated, and similar codes were combined by comparing their meanings, to decrease the number of the codes. For example, one interviewee answered the question of how he/she formed a group as "*I usually just look around and team up with those who are sitting nearby*." We assigned a code "physical proximity" to the above sentence. Secondly, after initially analysing the data, a report consisting of the data analysis procedures and the codes with representative quotations was sent to two other researchers for verification. This led to some renaming of the codes that caused misunderstanding or confusion. Thirdly, the current codes were used as a priori coding list to apply to the new data (the remaining transcriptions). This step resulted in a few new codes. After this, all the codes with similar meanings were combined into categories. For example, codes of "*group member familiarity*", "*getting to know people*", "*physical proximity*", "*task motivation*", and "*group members' commitment*" were combined into one category – "similarity", which represents that students voluntarily form a group based on similar attributes. This step was closely discussed with two other researchers.

RESEARCH RESULTS

Challenges and gains of multicultural student group work

Challenges and gains that students mentioned from their multicultural group work experiences. The challenge of "communication style" refers to the differences in how to communicate due to culture differences. Both domestic and international interviewees mentioned this challenge. Due to the lack of understanding of different cultural communication styles, it sometimes leads to misunderstanding and even a negative view about each other. One domestic interviewee mentioned: "So, like Dutch students, we communicate a lot about what we are doing and how far we are. But I heard stories about internationals who don't do that often, and they only say I finished this. I would like to say it makes us [Dutch students] uncomfortable." (Interviewee, #2). Similarly, one international interviewee mentioned: "Another big challenge for me was Dutch students' directness. For example, if they are not positive about what you refer to, then they would say it directly. Sometimes, I don't perceive it as polite" (# 10).

The challenge of "language issue" refers to either the English proficiency or speaking Dutch, which hinders the group communication. Domestic interviewees often mentioned poor English: "So, you have a little struggle with language when working with international students. Not every international student can speak good English" (# 4). International interviewees often mentioned the issue of domestic students speaking Dutch: "If all other students in a group are Dutch students, then the biggest struggle for me is language, because they will start speaking Dutch" (# 1).

The challenge of "extra efforts to collaborate" refers to extra efforts to work with international students because of their different backgrounds, only mentioned by domestic interviewees. "I think it is just because international students are so different in their background. So, when we work with them, we really have to take extra time thinking and learning how to work with one another" (#7).

The challenge of "feeling distanced" refers to the feeling of being separated from the group only mentioned by international interviewees. "The major challenge I can think now is that I do not feel close to them [Dutch students], or sometimes I can feel distanced. As I said, we were just there to finish the work together, so nothing else would happen. Sometimes, it can make me feel quiet frustrated" (#10).

Interviewees also mentioned gains or valuable aspects of working in a multicultural student group. They agreed that a multicultural group can bring different views to the group task, i.e., "different value". For example, one domestic interviewee mentioned: "people from other countries have different views, and they look at problems completely different, so that is very good" (#3). One international interviewee mentioned: "People with diverse background have different ideas and different study experiences, that gives many innovative ideas to group project. It is also a good way to learn from each other's culture" (#8). Two domestic students mentioned that they have learned collaboration skills and improved their English skills in multicultural group work.

International interviewees seem to be very certain about the value of having Dutch students in their group. "They [Dutch students] know their education system better, and they know professors and hence they know the proper way of talking with professors" (#1). "Some assignments require us to read some local materials or to understand some local backgrounds, so we need domestic students in a group" (#8).

Cultural differences of multicultural student group work

We asked students' perceptions about cultural influence when they work in multicultural group, and only two international interviewees (Chinese) gave examples.

One Chinese interviewee appeared to mention the difference in learning orientation between Dutch and Chinese students. "I once had a course called Sims Design. We had a group of seven people: four Dutch students, two Chinese students, and one international student. For the Dutch students, they emphasized more on the learning process, like learning how to design the multi-structures with peers. However, for us, Chinese students, we emphasized on the learning outcomes" (#9). According to Vermunt & Vermetten (2004), the concept of learning orientation consists of five categories: personally interested, certificate oriented, self-test oriented, vocation oriented, and ambivalent oriented. This Chinese interviewee seemed to express that Chinese students are more outcome or certificate oriented, such as striving to obtain a good learning results and/or credit points; Dutch students are more personally interested such as studying for interest in course subjects. Another Chinese interviewee addressed a difference in cultural communication styles. "I experienced cultural differences. For example, in the Netherlands, if someone is not involved in the group work, then other Dutch students will just kick him/her out directly. But this seems really rare in China" (#8). According to Gesteland (2012), cultural influences bring difference in how to communicate, and one of the communication styles is directness. As this Chinese interviewee mentioned, Dutch students are more direct in communication: people should be honest and direct – tell it as it is; Chinese students are less direct: it is best to talk carefully with people when you are unsure about their feelings, and most of the time, you want to preserve relationships.

Although a domestic interviewee did not personally experience cultural differences, he heard about cultural difference and this also affected his participation in multicultural group work. “I did hear stories from people who have worked with international students, for example Chinese students. So, their way of collaboration is different than ours. And that reminds you to probably avoid working with them [Chinese students], if it is your first group work. Because at the end, I would like to work as close to my normal working style as possible” (#2).

Two other interviewees mentioned that similar subject backgrounds will reduce the obstacles caused by culture differences in multicultural student group: “I feel like people I have worked with are mostly the same as me, because we are all doing physics. That kind of overcomes cultural differences” (#5).

Factors that influence multicultural student group work

In this section, the findings are presented in line with the input-process-output model.

Input – group composition processes

“Group composition” is an input attribute, and four factors (main categories) were found: similarity, difference, and group size, and separate community.

The main category “similarity” refers to interviewees’ perceptions of preferring to work with similar others. Four subcategories were found under this main category. The “familiarity” refers to interviewees often choose who they are acquainted with to do group work together. Dutch interviewees often mentioned they tend to work with friends: “If we know we can pick up ourselves, we usually get a text message from friends. ‘Hey, do you want to be in a group with me?’ That is usually how it goes. That makes kind hard for international students to join. Because usually we have already decided on the groups before the start of the course” (#3). International interviewees often mentioned they tend to work with someone they know: “So in my case, I don't know everybody very well at the first phase. As long as the teacher said that [form a group with three people], I would approach to the people I already knew before” (#10).

“Physical proximity” refers to that interviewees tend to work with those who are closer to them in geographic location than those who are distant, when they hardly know anyone in the classroom. “In Fusion, it is such a small class, usually, you just ask the person who is sitting next to you or sitting in front of you to form a group” (#2).

“Commitment” refers to that interviewees prefer to work with those who take responsibilities for doing the group tasks: “The most important thing is that people want to take their responsibilities and just do their parts as they promised” (#7). “Task motivation” refers to interviewees prefer to work with those who are interested in subjects and are motivated to do the group work, only mentioned by domestic interviewees. “I had an experience of working with international student in Portage. That went well, because if you looked at the people with right skills and if they are motivated, then it is not a problem working with them” (#6). “Gender” is only mentioned by one international interviewee: “It would be better if a group has a girl member, and then the communication would become better” (#8).

The main category “difference” refers to interviewees’ perceptions of working with peers with different nationalities, i.e., mix of nationalities, only mentioned by international interviewees. If the mix of nationality within a group is not roughly “in balance” (i.e., approximately 50:50), then the “token member” situation can occur. In that situation, Dutch students were reported to start talking Dutch amongst each other. This is not in line with the university international classroom and makes the only one international student feel distanced and isolated from the group.

The main category "group size" refers to interviewees' perceptions of the proper number of students in a group. Interviewees mentioned that group size influences the group discussions and group morale, and proper number is around four to five persons. If it is more than that number, the discussions and exchanges of information are difficult to control, and if it is only two people, then it may be good for building the interpersonal relationship but not good for the information elaboration.

The main category "separate community" refers to the "loosely coupled" parallel communities between domestic and international students. "Dutch people don't go to the internationals to say, 'do you want to join my group?' The international students also don't go to the Dutch people to say, 'may I join the group?' It is both ways" (#6). An international interviewee mentioned that "there is like only one or two international students in my department. Dutch students would have their own WhatsApp group, and they know each other. They would make a group. So, I don't have the chance to do that" (#8).

When we asked interviewees how to facilitate a good mix of Dutch and international students, they refer to the role of teacher. A Dutch interviewee mentioned: "I think it would be some more mix between international and Dutch students. I always prefer to have groups already pre-made. Because I didn't do my bachelor at the university but in Enschede [other university nearby] and even I felt a lot of times like 'I don't know everybody, how do I find a group member or do I just do it alone.' I know especially for international students, that is even harder, because at least I speak the language" (#3). An international interviewee mentioned that "As an international student, I feel more comfortable when the professor made the group, so they [professor] decided. Because I don't know so many people in the class. It is hard to just approach random person and try to ask them 'can I join you?' (#5).

Transition process

The group transition process includes the preparation and planning activities towards task accomplishment. According to the interviewees' statements, once the group is formed, group members will clarify the requirements, specify the goals of the group work, divide the work, and set deadlines for next group meetings. Therefore, specification of group goals and division of group work are often linked together.

"Goal specification" refers to some goals that students set or try to achieve based on the requirements of the group work, for the purpose of completion of the group work. Four subcategories of goal specification were found. "Grade" means the grade an individual group member aspire/expect to achieve at the end of the group work. This was only mentioned by domestic interviewees: "We go through the group grade [ambition] and the assignment" (#6). "Time schedule" refers to the time management activity such as scheduling group meetings. "I think at the beginning it is mostly like when and where we are going to sit. Because of the different schedules, it is mostly about practical things" (#3). Only one domestic interviewee clearly mentioned a personal learning goal: "For me, it always has been we get to know what everyone wants to get from the course at the start of the project. So, I usually said that I want to learn some from this course, and I want to do that extra bit" (#7). Similarly, one domestic interviewee mentioned the task goal: "I believe we always first discuss the goals, so what do we want to do in this week (#4).

The main category "division of labour" refers to interviewees' perceptions of the division approach of the group assignment into individual tasks. "Voluntary" is the most often mentioned task division method. "Mostly it is like we sit together on the first day, and we say 'I do this, what about you?' And somebody says 'ok, that might be an interesting task for me and then just pick it up.' Sometimes, there are people who do not say anything and then they get whatever is left" (#1). The reason for the voluntary division is probably due to the lack of comprehensive analysis of the task requirements/deliverables. "Expertise" refers to that interviewees make a connection between the tasks and their subject backgrounds. "So, we did pick each other's skills that were best suited for certain element. And then we do want to learn from each other. We distributed the workload even based on the skills of each group member, but we did mingle, and everyone has to work on every aspect of the work" (#7).

The main category "challenge" refers to the issue caused by division of the labor mentioned by two interviewees, i.e., the conflict between efficiency and learning. One domestic interviewee mentioned: "I once had a course where we have to work with a software [program]. I didn't experience that [software] before but one guy in my group was really good at it. I want to learn from his expertise, but he was just too quick to solve it. Actually, it is a really big workload, but he can solve it very quickly, which was nice for the group, I guess. But now I meet the problem that in my thesis I have to use that software. I really want to learn it at that time, but he was just too quick and there was a lot of time pressure, so I just let it go" (#7). One international interviewee mentioned: "I think it is the result of division of labor. The division of labor is for efficiency, so it is good for everyone to do what they are good at. For example, if you are good at writing, then you are responsible for writing introduction, which requires the ability of generalization. I once had a very difficult assignment, and most of us don't know how to do. We just let those who can do the hard part do it, and for those who can't, we may fill in other parts" (#8). Both domestic and international interviewees mentioned the conflict between efficiency and learning. However, the domestic interviewee perceived that group work experience as really bad experience and it was a pity that she failed to achieve her learning goal. The international interviewee seemed to perceive it as reasonable and the aim of division of labor is achieving efficiency and getting a good grade.

Action processes

After the preliminary formulation of the plan and division of the group work, it enters the action process, including group cooperation activities. Among the group cooperation activities, we have selected two key events that contains conflicts: disagreement and lagging behaviors. We also pay attention to interviewees' perceptions on the group atmosphere, such as whether they feel free and comfortable to express their ideas in a group. We illustrate the differences between the perceptions of domestic and international students on these topics.

"Disagreement" refers to the situation in which group members have different opinions on the assignment. Interviewees mentioned two approaches they used to solve these disagreements: "explanation until agreement" and "compromise". Students often use explanation until agreement method. For example, one domestic interviewee mentioned: "Most of the time, the reason people have a different opinion is because it is not all clear. We usually sat together, and try to write down what was really happening on paper. Then we had a discussion, and the third guy gave opinion on the disagreement" (#4). An international interviewee mentioned: "Normally it takes a long time. For example, if the group meeting lasts one hour and we will spend 40 minutes to discuss the disagreements" (#9). Solving disagreement seems difficult in project work in many cases and interviewees further mentioned that they would consult teachers if an agreement cannot be reached.

The other approach, “compromise”, namely a way of reaching agreement in which each person or group gives up something that was wanted in order to end an argument or dispute. The approach of “compromise” is often found under the specific condition of a group member insisting and pushing his/her opinions. One domestic interviewee mentioned compromise because of *conflict-avoiding*. “It was an open assignment, and there were many ways to solve that. There were two girls in my group who really wanted to do things in their way. They always say ‘you should do in another way, and you should do like this’. At the end, we did as they wanted just to get rid from them. But it turned out their way is not very good. We had another chance to improve our grade. This time, we did that part in the way we wanted, and it turned out to be better. It is always difficult to have a good discussion about how you want to do something especially in a team where people really want to push their opinion” (#6). One international interviewee mentioned compromise because he perceived it is *not worthy*: “Sometimes, you have disagreements, and it depends on the person how you will handle it. It takes me a lot of efforts to argue with them and show them that I was right. Then I just listen to them. Some people are very evident that they need to prove they are right, but sometimes I feel it is not worthy. For me, I am always like if I am stressed, I am just going to do what they say and then it is done. Because I don’t really care and don’t want to get into it” (#1). Another international interviewee mentioned compromise because of *helplessness*, because she just came to the Netherlands for the master program and was not confident in speaking English. “There were three people in my group, including me. Two of them have been arguing. But I really can’t understand why they are always quarrelling, because in my eyes, this task is very simple. Every group meeting, they would discuss about their opinions for 2 to 4 hours, and it really made me uncomfortable. That group work was really terrible and painful, so I even wanted to quit from that group” (#8).

“Lagging behind” refers to the progress of group work has been lagging. To catch up, domestic and international interviewees mentioned different ways to do this. Domestic interviewees often mentioned “direct remind” to cope with the lagging behaviour: “Usually he/she gets the stress from the group. We spoke to him/her ‘hey, you are not doing the work and please do it now.’ If it really gets bad like he/she really doesn’t put anything in the work, then we normally either told teacher or left his/her name out of the report. That was the worst thing you can do probably. But it often doesn't come to that bad” (#2).

International interviewees mentioned more diverse approaches to cope with the lagging behaviour than domestic interviewees did. One international interviewee mentioned “accept”, i.e., if a member is lagging behind, then other members in a group would do his/her assignment for him to catch up. “While I had a group where two people didn't almost do anything. We were four, so me and the other person try to push them to do something, but then the deadline came, and they weren't doing anything. So, we just did it for them” (#5). Another international interviewee mentioned “offering help” to deal with the lagging behaviour: “We are going to share progress with each other in each meeting. If we see someone is lagging behind, we are going to help. Normally we don't blame someone, probably they have some personal issues. We just try to help and solve together” (#9). One international interviewee mentioned “self-study” to deal with the lagging behind, because he perceived himself as the one who caused lagging behaviour in the group. “In my experience, I am the one left behind most of the time. But I still have to solve it myself and nobody is asking it”. When we further asked him if he would communicate with group members about like what and where made him stuck and unable to continue. He replied: “In the group discussion, I would not propose this. It feels kind of embarrassed to me. I would take extra time and extra efforts to understand it. Till the next meeting I would ask them questions from my own research. Then I would ask them to explain to me” (#10).

“Group atmosphere” refers to the group dynamics that makes the group members feel free and comfortable to express their opinions. Domestic and international interviewees expressed different perceptions about the group atmosphere (here we refer to general perceptions of group atmosphere instead of specifying working in a mixed nationality group). Domestic interviewees mentioned they are free to express their opinion in a group: “I always feel free to express. I never feel that I should keep my mouth shut or people don’t appreciate my opinion. I feel comfortable to say what I want to say” (#2). Other domestic interviewees mentioned get-to-know before they feel comfortable to express opinions: “In the beginning I often wait a bit, because I need to get to know people, know how they will react and how they work. After a while, I would like to just express myself and be clear about my opinions” (#3).

International interviewees seemed to be more hesitant to express their opinion in a group compared with domestic interviewees. International interviewees mentioned they only do this when they are certain about their idea: “sometimes, I feel maybe this idea is not mature enough to propose in the group, then I just keep it to myself” (#10). One international interviewee mentioned that it also depends on the group relationship: “If the group has a very close relationship among group members. I can share my opinion and ask what they think about. But if the group relationship is much further and people are separated, then I will weigh my words a bit” (#8). The above difference in perceptions of group atmosphere between domestic and international interviewees may be related with cultural communication style – expressive (Dutch) vs. reserved (Chinese) (Gesteland, 2012).

CONCLUSION

The TU/e International Classroom aims at creating a diverse learning environment where both domestic and international students engage in and appreciate multicultural teams. There are currently many types of group assignments that indeed offers students opportunities to experience that at the university. This study aimed at getting an understanding of domestic and international students’ perceptions about their multicultural student group work experiences in the current international classroom at the university.

To answer our first research question, both domestic and international interviewees mentioned their appreciation of different values that international (domestic) students bring to the group, so they did not show a strong tendency to refuse to work with each other as a group. Meanwhile, they reported certain challenges such as different communication styles and language barriers when working in a multicultural group. To answer our second research question, not so many interviewees (only two international) can sense and tell the cultural influence on their group collaboration behaviours. On the one hand, it may mean that students have an open and tolerant attitude towards different cultures, so they do not feel that cultural differences influence their group work. On the other hand, it may also mean that students are likely to be unaware of cultural differences and even the multicultural learning. To answer our third research question, we found similar factor that influences students (domestic and international) joining in a multicultural group. For example, both domestic and international interviewees preferred to work with someone they already know. However, we also found different factors perceived by domestic and international interviewees that influence their group work behaviours. For example, domestic interviewees tended to mention “task motivation” and international interviewees tended to mention “mix of nationalities” as factors to consider before joining a multicultural group. Difference in students’ perceptions of how to do the group work, such as division of task and disagreement solution between domestic and international interviewees were found. The factor of culture seems to play a role in interpreting the above differences.

Based on the results, we concluded that the vision of an international classroom has not yet been achieved. It provides a basis for discussion on how to move the vision forward. Next steps would focus on comparing group collaboration behaviors and performances with members of varying nationalities (balancing groups and random formation) to see the diversity effects. Future research could empirically test the factors that have an influence on input-process-outcome of multicultural student group work by means of a questionnaire.

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GAUGING THE IMPACT OF CDIO AND MOMENTUM FOR FURTHER CHANGE

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ABSTRACT

Recently, within the CDIO community, there has been a focus on the impact of CDIO and an emphasis on how engineering education will change in the future due to the rapidly changing technological world (Industry 4.0). This paper focuses on the results of a new alumni survey, based on an original survey at the authors' School in 2004, but with the objective of understanding the subsequent impact of 12 years of CDIO graduates and also benchmarking and determining if there is obvious momentum for future curriculum change. Specific areas that are discussed include:

- A comparison with the previous alumni survey to understand key syllabus topics (i.e., programme learning outcomes and their hierarchy).
- What has changed after 12 years of CDIO graduates?
- A reflection on 15 years of CDIO implementation.
- The engineer of the future – are there any obvious influences on engineering education in 9-10 years (2030)?

Overall, it appears that CDIO curriculum implementation in the School over the past ten years has been accompanied by an increase in the skill levels of graduates in several key areas. Further work will be carried out to assess the suitability of current programmes for the expected technological and societal needs of stakeholders moving into the next 10 years and beyond.

KEYWORDS

CDIO, graduate skills, survey, curriculum design, Standards: 1-12

INTRODUCTION

The School of Mechanical and Aerospace Engineering at Queen's University Belfast has been a collaborator in CDIO since 2003 and has an ongoing change management plan for curriculum reform based on the CDIO principles and methodology. In 2004 the School developed and implemented a new degree programme based entirely on this ethos and has been progressively feeding this pedagogy and experience back into its other degree programmes. In addition, it has been disseminating this best practice internally within its university and at regional and international CDIO events in subsequent years. The School has therefore gained experience in key pedagogical areas such as curriculum change management, workspace design, active and interactive learning, introductory courses, mathematics provision for engineers, peer assessment and review, project and problem-based learning, and the collaborative quality enhancement of programmes. The School is now keen to evaluate the impact of CDIO. In 2004, the School carried out an alumni survey, which is presented in Chapter 3 of the CDIO book (Crawley et al. 2007) as part of a bigger project to ratify and define the CDIO Syllabus. Since then, other CDIO collaborators have used such alumni surveys to not only benchmark their engineering curricula, but also to check proficiency levels against the CDIO syllabus and gauge effects on educational quality.

The aim of university engineering programmes should be to equip graduates with the technical, personal, and professional skills required to meet the ever-evolving needs of industry. As we move into the fourth industrial revolution, "Industry 4.0", paradigm shifts are expected in the way that we work, live and interact with others, driven in particular by rapid technological advances (Marr, 2018). Kamp (2020) refers to Industry 4.0 evolving into "Society 5.0" and states *"Every system, product or service, including higher education, will have aspects or parts that are dramatically enhanced or disrupted by digital technologies. Anything that can be automated, will be. Routine tasks are becoming increasingly automated, while newly created jobs require different competencies."* Additionally, the global crisis caused by the COVID-19 pandemic may have significant and lasting influence on the way in which industry operates. This has brought about obvious challenges but may also serve as a catalyst for change and a driver for the introduction of disruptive technologies. It is therefore unlikely that the way in which industry operates will return to the pre-pandemic status quo.

The CDIO engineering education model was designed to develop well-rounded graduate engineers who have appropriate skills for modern industry, and it is therefore important to reflect on whether the existing model continues to meet their needs in their professional lives and supports the needs of industry both now and into the future. This is particularly important at this time of rapid change. The importance of adapting curricula, and benchmarking programmes to achieve these aims has been previously reported on in many studies (Bankel et al., 2005; Cloutier et al., 2012; Crawley & Malmqvist, 2007; Lang et al., 1999; Malmqvist et al., 2005). Numerous papers have reported on how CDIO has been implemented in different institutions (Schrey-Niemenmaa et al., 2010; Sparsø et al., 2007). In addition, some studies have since reported on a review of the effect of CDIO curriculum implementation as measured by a variety of indicators (Edvardsson Stiwne & Jungert, 2010; Huiting, 2014; Malmqvist et al., 2015)

Feedback from alumni is one means of gaining valuable insights into current needs in industry (Mechefske et al., 2005) and can shed light on the continuing relevance, or otherwise, of aspects of curricula, including identifying gaps in provision and allowing for future planning. In 2004, a series of studies were carried out to assess the extent to which individual engineering programmes met the needs of the CDIO Syllabus, and then in turn to determine whether they were fit for purpose as seen through the experience of alumni who were working as engineers in industry. Stakeholder surveys were carried out to assess the personal, professional, interpersonal and product, process and system building skills expected of graduate engineers, as well as opinions on the importance of aspects of the curriculum. The results of these surveys were presented in the CDIO book (Crawley et al., 2007), and in individual papers by the universities involved (Armstrong et al., 2006; Armstrong & Niewoehner, 2008; Wyss et al., 2006). The specific programmes considered were as follows:

- Mechanical engineering at Chalmers University of Technology
- Mechanical and materials engineering at Queen's University, Kingston, Canada
- Applied physics and electrical engineering at Linköping University
- Aeronautics and astronautics at Massachusetts Institute of Technology (MIT)
- Mechanical and manufacturing engineering at Queen's University, Belfast (QUB)

The authors from the School of Mechanical and Aerospace Engineering at QUB decided that it was of interest to obtain an updated review of opinion about the experience of the degree programmes in the school to ensure that they continue to provide the skills and knowledge necessary for a career in the ever-evolving engineering industry. It was of particular interest to assess what effect, if any, has resulted from implementation of the CDIO-based syllabus within the school since the first graduates who completed a "full" CDIO programme completed their studies in 2010. Some previous follow-up surveys have been carried out by other institutions to assess the effect of the implementation of the CDIO syllabus, (Edvardsson Stiwne & Jungert, 2010; Malmqvist et al., 2010), but this study covers a longer time period since implementation, and also assess the effects of the past ten years of technological change. In addition, engineering programmes continually need to adapt to the wider technological and societal changes that take place, which are often reflected in accreditation requirements. For example, the UK Engineering Council's AHEP 4, which was published in 2020, calls for "***a sharper focus on inclusive design and innovation, and the coverage of areas such as sustainability and ethics. The coverage of equality, diversity and inclusion is also strengthened to reflect the importance of these matters to society as a whole and within the engineering profession***." (Engineering Council, 2020). There is also a clear need for increased focus on preparing graduates for a society in the shape of the UN's Sustainable Development Goals, and this will play a significant role in the new QUB strategic plan.

METHODOLOGY

For this work, the intention was to closely follow the work described above to acquire a more contemporary appreciation of stakeholder views to guide both the content and learning outcomes employed in the authors' programmes. In order to provide a direct comparison with the 2004 survey, an email survey was prepared with identical questions. An additional space was provided to allow respondents to provide free-form comments. A database of alumni from the School of Mechanical and Aerospace was obtained from the Alumni Office within the university. These included only those alumni who had consented to be contacted by the university for such purposes. The database was filtered to select only those who had graduated with relevant degrees, and to remove any alumni who had proceeded to subsequently qualify in other areas such as finance or law. The final pool contained 1002 contacts. The survey was sent on the 5th March 2020, just 2 weeks before the UK entered a national lockdown due to COVID-19. It was subsequently decided to send the survey out again to non-respondents in October 2020. The data received was analysed and compared with the data from 2004. In addition, the qualitative comments from alumni were considered.

RESULTS AND DISCUSSION

Number of Responses and Demographics

The initial survey that was sent in March was successfully delivered to 978 email addresses (97.6%) of contacts. The subsequent follow-up email was sent to those recipients who had no engagement with the original request. In total 89 responses were received from the survey. This was lower than expected but was most likely heavily impacted by the COVID-19 pandemic. This number compares with 143 responses from the original survey in 2004.

According to the data received, 17 of the alumni were female and 72 were male. This would be in line with the general graduate population from the School, where typically around 18-20% of students are female. 57% of respondents graduated from Mechanical or Mechanical and Manufacturing degrees (Table 1), and most respondents graduated after 1990, (Figure 2). 85% of the respondents are currently located in Northern Ireland, the Republic of Ireland or Great Britain (Figure 3).

Table 1. Degree Programme Breakdown

Aeronautical Engineering	Aerospace Engineering	Manufacturing Engineering	Mechanical & Manufacturing Engineering	Mechanical Engineering	Product Design & Development
27%	13%	1%	11%	46%	1%

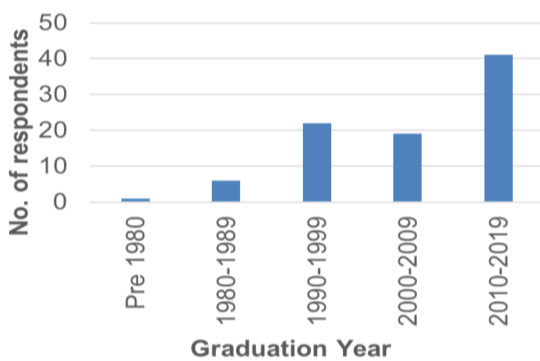

Figure 2. Respondents by graduation year

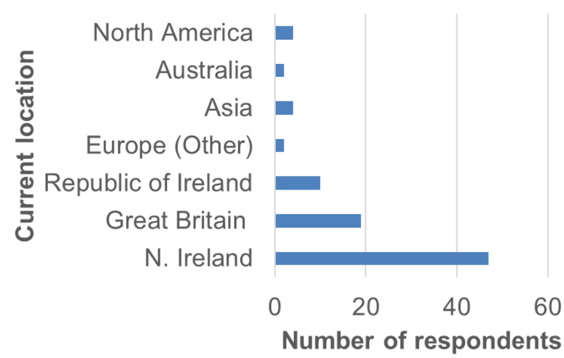

Figure 3. Respondents by location

Ranking of Subject Importance

The survey asked alumni to rank the importance of having knowledge of several core mathematical and engineering science topics. The ranking of the importance of mathematical topics is shown in Figure 4, indicating increases in the perceived importance of several topics between 2004 and 2020, with the clearest increases in the areas of transforms, complex numbers, calculus and vector calculus. This may be due to the increased need for expertise in areas such as computer programming and modelling. Slight decreases in the importance of traditional mathematical topics such as geometry, trigonometry and algebra are seen. For engineering science modules (Figure 5), alumni continue to place high importance on having a basic knowledge in the three main areas of Thermodynamics & Fluid Mechanics, Statics and Strength of Materials, and Engineering Dynamics, although this has fallen slightly between 2004 to 2020. There has been no notable change in the perceived importance of understanding the relationships, variables and parameters in the three main areas or in the importance of being able to write down and apply equations in calculations.

Topics additional to the core modules include those related to electrical and electronic engineering, production and manufacturing, and business and enterprise. The comparison of the perceived importance of these is shown in Figure 6. Increases in perceived importance are apparent in the areas of electrical and electronic engineering, computer programming skills and related areas. This is not unexpected due to the rapid increase in the use of computer aided systems in manufacturing, production, and research and development, linked into the

Industry 4.0 shift. Some small decreases are seen in the importance ranking of a variety of business and enterprise areas, while all other areas remain relatively unchanged.

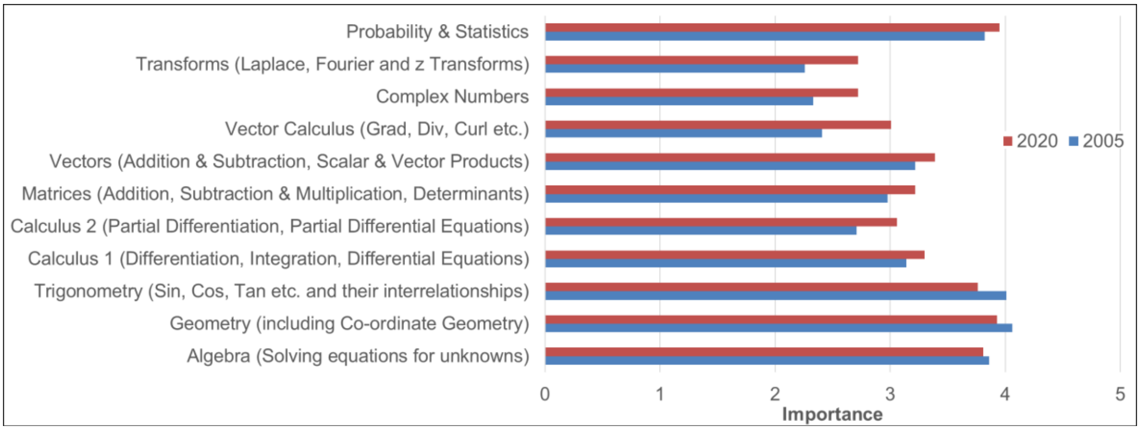

Figure 4. The importance of mathematical topics to alumni

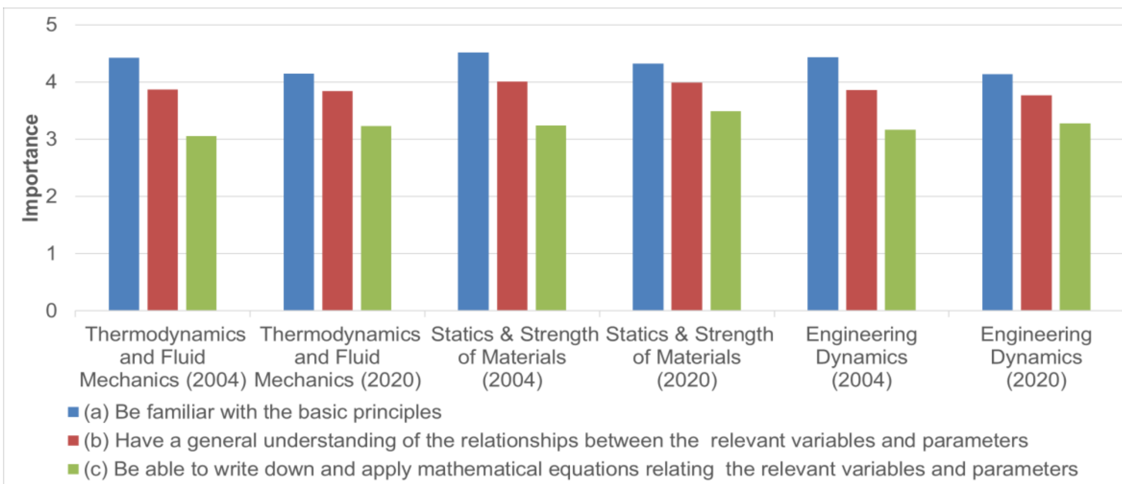

Figure 5. The importance of engineering science modules to alumni

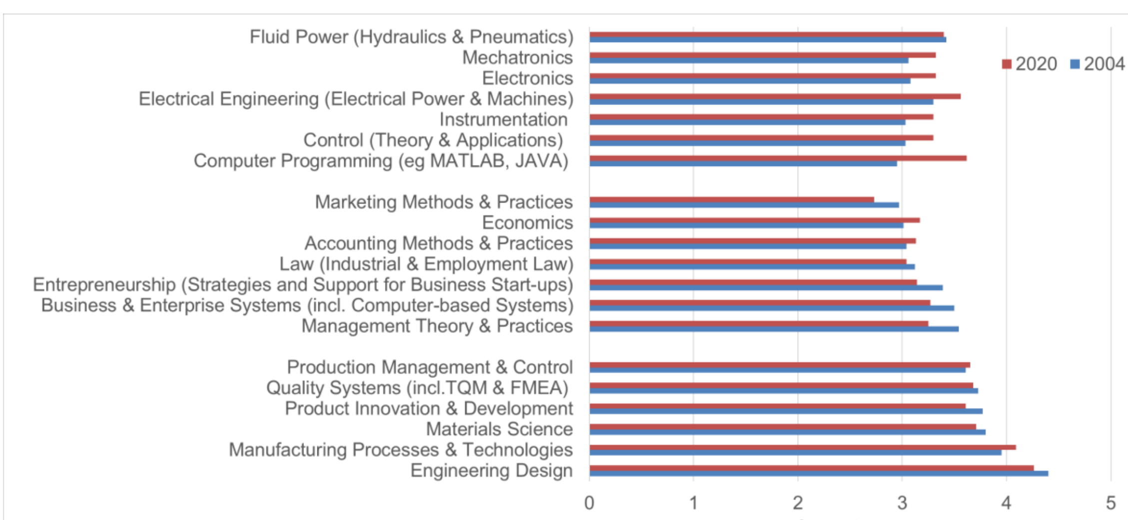

Figure 6. The importance of additional modules to alumni

Ranking of Skills

The results in Figure 7 show the ranking of the importance placed by alumni on several graduate skills. When this data was presented in 2004 there was an adjustment of the data to fit with the ranking scale used by other institutions. Here we compare like-with-like with no scaling applied. In addition to the ranking of "importance", alumni were also asked to rate their own skills in these areas at graduation. The ratings of importance for both years are very similar for the majority of skills, but a modest but notable increase can be seen in all the Conceive-Design-Implement-Operate areas 4.3-4.6 from 2004 to 2020. Alumni ranked their own skills at graduation relatively low compared to their perceived importance of skills in all areas. The most closely matched perceived skill level relevant to the importance of the skill was in designing, followed by personal skills and attributes and communication skills. The biggest discrepancy in skill level relative to importance was in engineering reasoning and problem solving followed by the two key CDIO areas of Implementing and Operating.

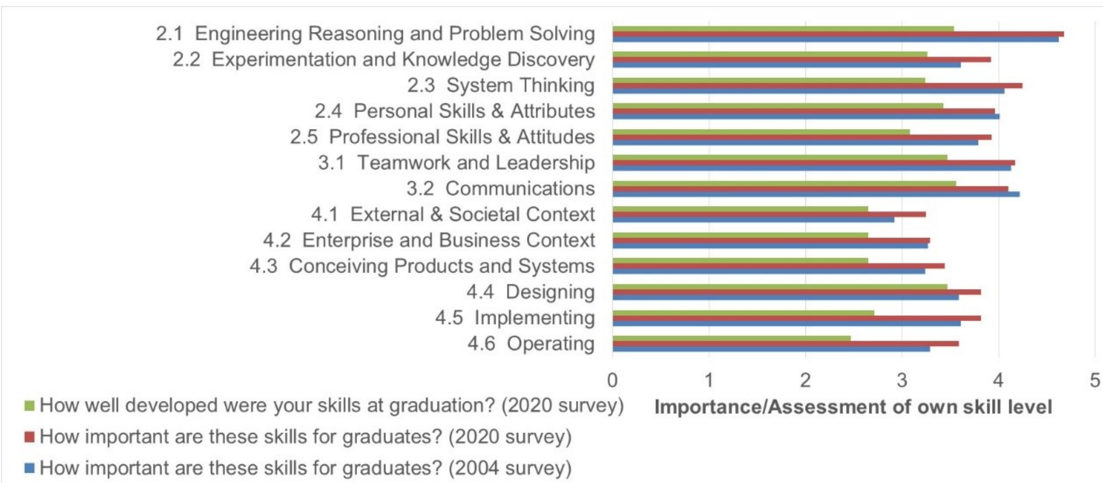

Figure 7. Ranking of the importance of skills, and perceived skill levels at graduation

The difference in perceived skills level between alumni who graduated after 2010, when the CDIO syllabus had been fully implemented was then compared with those alumni graduating before (Figure 8).

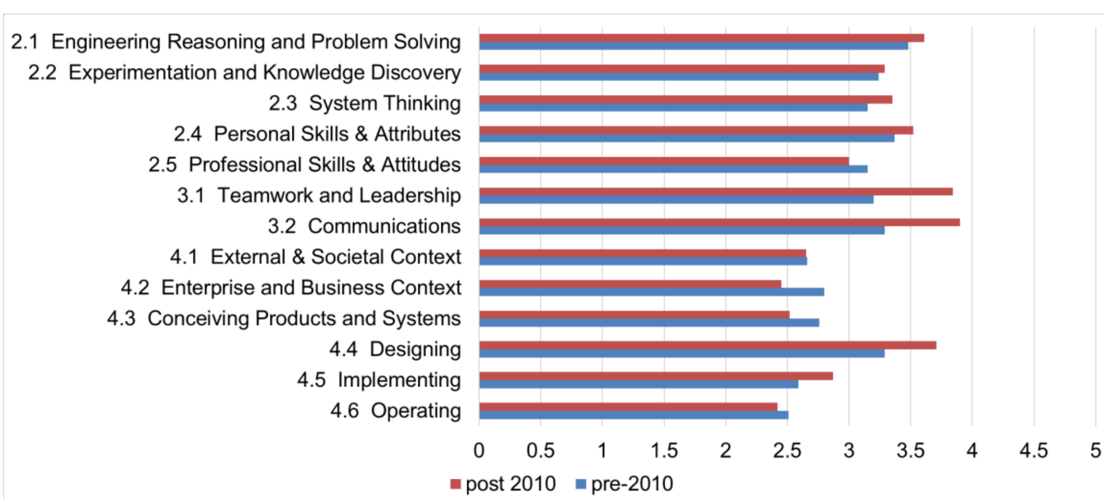

Figure 8. Perceived skill levels at graduation pre- and post-full CDIO syllabus implementation

Post 2010 graduates reported higher self-assessed skills in a few key areas, with the greatest improvement seen in teamwork and leadership and communication skills, this ties in with findings from two studies from Linköping and Chalmers (Edvardsson Stiwne & Jungert, 2010; Malmqvist et al., 2010). This was followed by improved design and implementation skills. Some decreases were seen in the areas of enterprise and business, and in conceiving products and services. Results suggest more work is needed in improving some key skill areas.

Comments by Alumni

Comments written by the respondents can be grouped into 5 main categories: Technology, Teamwork, Industrial experience, Professional Skills, and subject specific comments. The numbers of comments in these areas are presented in Table 2. The comments have been grouped by whether the respondents had positive or negative comments about their experience in the area during their time at QUB, or if they commented that more time should be devoted to that area.

Table 2. Categories of Alumni Comments

	Positive comments	Negative comments	More required
Technology: Software, hardware, programming, electrical/electronic engineering	4		4
Teamwork: Group projects	2	2	
Industrial Experience: Placements, guest lectures, industrial visits, real-life examples	4		11
Professional skills: Business, enterprise, professional, soft skills	4		4
Subject specific needs	3		3

The area, which had the largest number of comments related to industrial experience, with respondents commenting positively on their industrial placement experiences. Alumni who graduated before the full implementation of CDIO also recommended more time should be devoted to developing students’ experience in this area through a variety of means:

“I found my placement year particularly useful, and gained most of the skills that have helped me in my graduate job whilst on placement” (Post CDIO graduate)

“[industrial placements] were not the norm in queens at the time which I felt was a shame…both [placement] experiences were arguably the most important of my degree - more so than the actual courses I studied.” (Pre-CDIO graduate)

“Real world problems should be further integrated within the course, such as guest lecturer from industry and attached team exercise. Visits to companies would also be very beneficial in the first few years, and encouragement of industrial placement.” (Pre-CDIO graduate)

Comments relating to the use of technology reflected the increased importance placed by alumni on having knowledge in areas such as engineering software applications, computer programming, control systems and electrical and electronic engineering:

"Tools like MATLAB, Excel & VBA have proved useful. Going into a work environment where these wouldn't be commonplace I've been able to help streamline & improve many work processes" (Post-CDIO graduate)
"Emerging and existing high-tech manufacturing equipment would be a good area to cover. Robotic control, advancements in robotics, developments in significant manufacturing processes…" (Post-CDIO graduate)

Experience of teamwork during the degree programme was reported as both positive and negative, even by the same respondents:

"Teamwork is great, but I feel too much of the marks in these modules was based off of other people and they could really drag down your score." (Post-CDIO graduate)

Finally, there were various comments relating to the importance of developing a range of personal, professional and business skills in engineering graduates:

"there are a host of supplementary skills (project management, team leadership, management of risks & opportunities, communication & influencing, industrialization challenges etc.) which are critically important to becoming a good engineer in the "real world". It is these 'softer' skills which could have more attention." (Pre-CDIO graduate)

"Some are also fairly poor at the basics required in work, i.e., computer literacy and professional conduct via email etc.…the stereotype of engineers still holds firm, and many lack the basic skills to integrate into a team and use the communication channels well." (Post-CDIO graduate)

CONCLUSIONS

The results comparing alumni views between 2004 and 2020 on the importance of a various aspects of the engineering syllabus at QUB, and the attributes and skills required in industry has shown the following:

- The alumni showed a remarkably similar opinions on the importance of most of the core engineering subjects in 2004 and 2020, with greatest importance placed on familiarity with basic concepts, followed by understanding variables and parameters, and then by the ability to perform calculations.
- For mathematical topics, slightly more importance is placed on transforms, calculus and complex numbers in 2020 compared with 2004. Other mathematical topics hold similar importance or slightly lower.
- In the area of electronics, electrical engineering and computer programming there is a small uplift in the importance placed by the alumni in 2020 compared to 2004. This may be reflective of greater use of technology in their daily and professional lives as we move towards industry 4.0.
- The key professional, personal, and business context skills deemed important by alumni have remained surprisingly constant in a number of areas. However, we note some increase in the rating of importance of the Conceive-Design-Implement-Operate areas in the more recent survey.
- Alumni perceptions of their own skill levels are generally low compared to the importance they place on each area.
- Comparing alumni who graduated before and after the implementation of the CDIO syllabus shows increases in perceived skill level in the areas of teamwork and

communication and in design skills, but further work needs to be done to improve other key skills in graduating students.

- The comments made by a number of respondents give an interesting insight from those in industry, highlighting the need to develop well-rounded engineers who are equipped for the world of work with up-to date technical skills supported by industrial acumen and appropriate professional and personal skills.

Overall, it appears that CDIO curriculum implementation at QUB over the past ten years has been accompanied by an increase in skill levels of graduates in several key areas. However, other areas still require further work to fully realise the benefits and aims of CDIO. Additionally, to meet expected technological and societal changes, further work will be carried out to assess the suitability of the current programmes for meeting the needs of industry and engineers as we move into the next 10 years and beyond.

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STUDENTS' READINESS FOR ONLINE LEARNING SYSTEM IN NIT

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ABSTRACT

The Coronavirus (COVID-19) outbreak has forced closure of educational institutions in Japan. In response to the prevention and control of this pandemic, UNESCO recommended the use of distance learning measures and open educational applications and platforms to reach learners remotely and limit the disruption of education. Therefore, many National college of Technology (hereafter NIT) are offering distance learning courses across the country. In an effort to continue the classes, Nagaoka National Institute of Technology (NNIT) has implemented online learning class. The goal of this study is to understand the effectiveness of the online learning from the student's readiness to continue it. Among the various classes undertaken, this study focused on English class. A total of 274 students from first and fourth year of NNIT participated in the survey and presented their perspectives. The results showed that the fourth-grade students preferred online learning as they could learn at their own pace and this format of learning was convenient for them. On the other hand, the first-year students preferred face-to-face classes due to the difficulties in time management and understanding of class content. Further, findings of this study also highlighted the benefits and challenges of taking online classes and effect of this pandemic on the students' readiness. Based on the student's opinions, the blended form of learning (i.e., face-to-face and online learning) was found as the most suitable format of learning. Therefore, it is expected that this study would assist higher education professionals in NITs to develop more feasible and supportive approaches for effective distance learning in near future.

KEYWORDS

National Institute of Technology (NIT), face-to-face classes, online learning, students' readiness, Standard: 2, 11

INTRODUCTION

There is no doubt that the coronavirus (COVID-19) pandemic has influenced global education system due to localized and nationwide closures around the world. According to the reports of

UNICEF (2020), more than 60% of the world's student population are being affected. In Japan, first corona patient was confirmed in the middle of January and the Prime Minister requested entire educational system to suspend their classes from the beginning of the March (NEWS, 2020). Compared to other countries, Japan emergency law does not allow to impose lockdown in the country. Therefore, Japanese government has appealed people to stay at home and avoid 3Cs (Closed space, Crowded space, Closed contact setting) during emergency period (Tashiro & Shaw, 2020). All education systems including institutes and universities is moving to digital learning or distance learning approach, avoiding traditional face-to-face classes.

One of Japan's most unique systems of higher education is the National Institute of Technology (NIT) system which combines high schools, universities of technology and other universities. At present, there are 51 colleges (55 campuses) across Japan and it has 5-year regular course starting from the age of 15 offering an associate degree. After finishing two more-years of advanced course, students get their bachelors' degree. Wedge shaped education is a special feature in its curriculum where junior students mostly learn general subjects and senior students mainly learn specialized subjects. It is designed to generate upward spiral of knowledge and ability improving their learning skills through three steps such as lecture phase, experiment phase and practical phase (Siswanto, Budiyono, Kasai, Fujiwara, & Mizuno, 2020). Through this curriculum, more practical engineers suitable for industries are produced with high creativity and humanity (Shimoda & Maki, 2018). After lifting of emergency of state in Japan in the end of May, NITs are opened, however most of them are still following distance learning patterns considering safety guidelines of UNICEF (2020).

Distance learning (or online learning) in Japan has undergone a major transition from postal system learning to streaming learning due to various telecommunication breakthroughs facilitating the worldwide access to Internet. Distance learning allows the learner and instructor to be physically apart during the learning process and maintain communication in a variety of ways (Beldarrain, 2006). The significant contributors for the development of distance learning in Japan are National Institute of Multimedia Education (NIME) and Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT) (Albrechtsen, Mariger, & Parker, 2001). At the beginning, several issues like administrative and faculty ignorance, culture of teacher-directed learning in face-to-face environment created conflict with the concept of distance learning which emphasized on the autonomy of the student and distant communication (Jung & Suzuki, 2006; Kubota & Fujikawa, 2007). However, distance learning practices have become popular as a result of the present pandemic outburst.

Online learning is an instruction-based learning between teacher-student or peer-to-peer that occur in different locations or at different times.In this study, we used online learning which are self-facing learning experiences using pre-recorded videos or recordings and pre-uploaded lecture materials such as PDF's, presentations that each leaner can go through the materials at their speed and review class materials according to their convenience. Because students have chance to study lessons at any time, they do not need to bother about joining the internet at a specific time. Learners can proceed their studies when it is convenient for them. Further supplementary materials help to improve their further understanding. The online learning is are more suitable for the students who are self-directed and have different kinds of experiences in education (Liyan & Hill, 2007).

The online learning environment largely differs between different institutions and few studies have already experimented with learning analytics of the students for checking their learning processes and self-regulation (Kubota & Fujikwa, 2007; Bart, Olney, Nichols, & Herodotou, 2020). Online courses are becoming the new normal mode of learning. Recently, its popularity has multiplied among higher education institutions due to the emergence of social networking technologies. The wide range of advanced technologies support constructivist environments for motivating and meeting the needs of the 21st-century learners (Cetin-Dindar, 2016).

Like many NITs in Japan, Nagaoka National Institute of Technology (NNIT) has also implemented an online platform to provide the most effective online education experience to the students. However, there are limited studies reporting the scenario of online learning in NITs. In order to find the suitable and effective approach for online education in NNIT, our study is an attempt to firstly understand the learner's perspective about online learning and secondly to utilize their feedbacks for educational guidance for developing the appropriate online education approach. In particular, since online learning at present context creates a huge impact on the formation of lifelong positive attitudes toward the future of education, a careful discussion is thought to be needed. To the best of the researchers' knowledge, no earlier survey has been conducted at NITs to investigate the perspective of students for online learning. Thus, the aim of this study is to understand the students' readiness on online learning in NNIT through the understanding of their preference and psychological readiness. Therefore, research questions addressed in this study are:
(1) How have students perceived the online learning?
(2) What are the key factors affecting online learning?
(3) Is there any significant difference in the preference of face-to-face and online learning for students in the different grades?

MATERIALS AND METHODS

The data were collected from first-year students and fourth-year students attending a special English communication class emphasizing on the essential thinking skills. In this course, the students practiced their essential thinking skills for problem-based learning activities and develop the ability to communicate in English as global engineers. This course is basically designed under English for developing generic skills which is gaining momentum in many engineering institutes in Japan. The details of this course could be found in the study by Tsuchida et al. (2020). The data was collected by using survey questionnaire.The questionnaire was prepared by the group of English teachers and it was clearly indicated that the anonymity of the respondents was guaranteed.The students were informed that the aim of questionnaire was to understand their readiness for online learning. The questionnaire was prepared using Microsoft Forms and sent to students via Microsoft Teams. Questions were written in both English and Japanese language for the easy understanding. The questionnaire consisted of 27 questions with the Likert scale ratings. Apart from the questionnaire, an assignment was also given to the students for more detailed data collection. The assignment was about writing logical essay about their preference on traditional face-to-face classes or online classes.

Data Analysis

The data were obtained with the help of Microsoft forms result analysis system. The structure of the survey allowed for both quantitative and qualitative data for analysis. The data were analyzed using the SPSS statistical software. Descriptive data were calculated to get the value of mean and standard deviation. Also, inferential statistics was performed for analyzing the differences in the responses.

RESULTS AND DISCUSSIONS

The questionnaire findings indicated that most of the students were clear about their preference for the new mode of learning. In other words, they had clear views about the face-to-face and online learning.

Qualitative Results

Demographic Results

Of the 274 students attending English class at the time questionnaire was made available, 238 students completed the entire questionnaire, resulting in 86.86% response rate.The respondents were 71.16% of male and 28.83% of female consisting of 169 first-grade students and 60 fourth-grade students. The average age of the first-grade student was 15 years and that for the fourth-grade was 18 years. When the students were asked about the online learning, 67.6 % percentage of the students reported that they were overall satisfied whereas 16% of the students were dissatisfied. It should be noted that 13.9% and 2.5% were very satisfied and very dissatisfied, respectively.

Time: Hours Dedicated for Online Learning

In terms of the internet use per day, it was found that 52% of the student were observed to spend 1-5 hours, while 47.5% and 0.4% of the students spent less than 2 hours and 6-10 hours, respectively. Similarly, 60.5% of student spent less than 2 hours searching for the information and rest of them 1-5 hours for it. Similar to this finding, the literature suggests that online learning is related to one's ability to manage time, experience, and the adoption of the learning environment (Vonderwell, 2004).

Statements about hardware and software

This study also revealed the preferred technological devices for online learning. Normally students (74.4%) used laptop/ desktop to submit their assignments. Most of the students (94.5%) generally used Teams for learning during their online learning. Very few of them 0.8%, 2.9% and 1.7% respondents used YouTube, Google Forms and other tools for learning in online learning. Almost quarter of the students preferred laptops or desktops over smartphones or tablets. The most preferred tool was Teams. For information security reason, Microsoft Teams was used for the entire lesson. As the surveyed students are quite young, this finding was similar to the previous researches, which suggest that the capability and confidence in the use of technological devices for young people are related to quick independent learning (Tang & Lim, 2013). Also, capabilities could be assessed through their competency in using these devices (Schreurs & Sammour, 2008). These findings further supports other researches that proposes ICT skills are an important factor in learner's preference and student's competencies and experiences in ICT skills are associated with their academic successes. (Menchaca & Bekele, 2008; Keramati & Kamrani, 2011; Harandi, 2015). These results also indicate the need for future researches on the easiness of using technologies for online learning.

Quantitative Results

The quantitative analysis of the responses from students was done for understanding the factors that affects the online learning. The questions were divided into factors such as stressors and nature of assignment. The similar questions were grouped under stressors such as the impact of pandemic on their studies, health issues, financial problems and motivation to study. Similarly, another set of questions were based on the nature of assignments.

Also, the independent and dependent variables to find the mean and standard deviation of each variables were analyzed. In this study, four scales were used to categorize the percentage of the mean score which are very high, high, medium and low since neutral point is biased (Raaijmakers, Hoof, Hart, Verbogt, & Vollebergh, 2000) as shown in Table 1.The mean score analysis showed the perception and behaviour of the respondent towards the online classes.

Table 1. Mean categories (Source: Cohen, 1988)

Group Code	Group Code	Category
1	1.00-2.33	Low
2	2.34-3.67	Medium
3	3.68-5.00	High
4	5.00-6.33	Very High

Stressors

The results of the stressors are shown in the Figure 1 and Table 2. It was observed that 47.1% of the respondents agreed to the effect of pandemic in their study and they are worried about it and 18.4% reported that COVID-19 did not impact their education. The percentage of mean score of the statement “Has COVID-19 impacted your education” was 3.97 indicating the high effect as stressor for online learning.The abrupt situation has created an atmosphere of uncertainty in the education system and the students expressed that they are trying to cope up with the new style of learning. For health issue, 56.7% students did not feel any stress/ health problems during online learning and rest of them i.e., 43.3% feel stress/ health problem during this time. The percentage of mean score of the statement “Do you feel any stress/ health problems during this time” was 2.83 showing the medium effect as a stressor on the online learning. Contrary to the results of research by Salari et al. (2020), the health issues and related stress rate were comparatively less in our study. The possible reason for this observation could be leniency of government restrictions in Japan. It is important to highlight the fact that unlike other countries, the Government of Japan did not enforce lockdown, and state of emergency was maintained for few weeks which might have caused less effect on the health of students especially in the countryside where the study site was located.

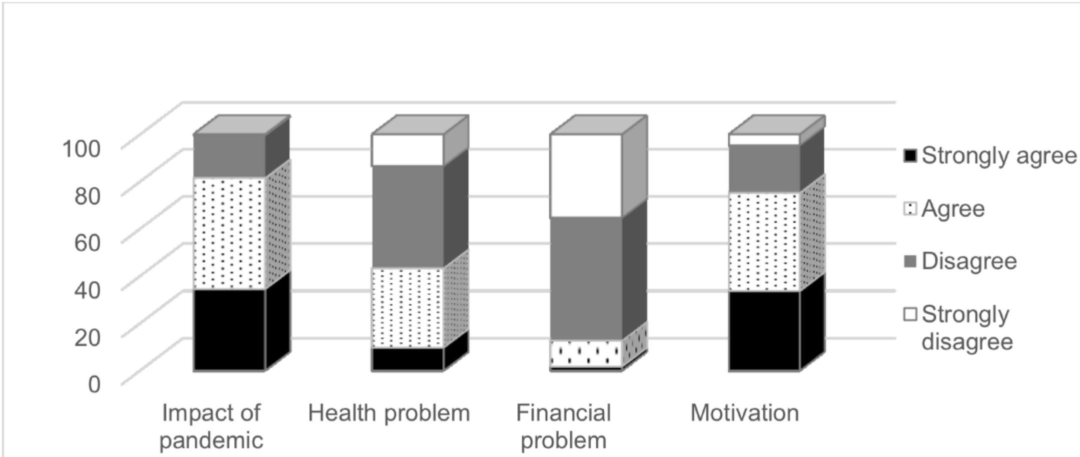

Figure 1. The effect of the stressors for online learning

Table 2. Mean score values of the stressors and nature of assignments

Question/statement	Mean	Std. dev
Stressors		
Has COVID-19 impacted your education?	3.97	1.06
Do you feel any stress/ health problems during this time?	2.83	1.29*
Did you find any financial problems during this time?	1.92	0.97
Would you like to join online classes in future?	3.79	1.23*
Nature of assignments		
Did you enjoy doing your assignment?	3.9	1.05
Did you understand the instructions of your assignments?	4.11	0.45
Was it easy to submit your assignments?	3.52	1.16
Were you worried about your study?	3.48	1.07
Do you think that the class was well organized?	4.39	0.75
Were the feedbacks helpful to you? *Note : Higher std.dev values indicate that the data points are spread out over a larger range.	4.32	0.95

Similarly, 52% of students strongly disagreed that there was any financial problems throughout the study period. The percentage of mean score of the statement of “Did you find any financial problems during this time” was 1.92 showing the lowest stressor value. The results also demonstrated that this new mode of learning did not impair their motivation to learn and almost half of the respondents were interested to join the similar kind of classes in future.

Nature of Assignments

One of the major challenges of distance learning is the assignments. This was the first time for the regular students in NIT to attend online class which was even more challenging as it is an English communication class. In most of the educational institutions, it has been reported that English class is one of the most difficult subjects to teach to Japanese students (Yoshihara, Kurata, & Yamauchi, 2020; Takahashi 2021).

We attempted to check how well the students perceived the prepared educational materials and exercises for the class. The assignments were given in the form of worksheet and there was an interview task at the end of the semester to ensure that they used their English speaking and listening skills with International students. The results showed that 47% of the students enjoyed doing the assignments since the instructions were easy to understand. The clarity of assignment materials was specifically expressed by 52% of the students. The percentage of mean scores of the statement "Did you enjoy doing your assignment/ Did you understand the instructions of your assignments/ Was it easy to submit your assignments?" was within the range of 3.68 - 5.00 exhibiting positive impact on their assignments. The students' responses underlined the importance of assignment clarity as a basic facilitator of independent study for online learning. Furthermore, after the submission of the assignments, they were evaluated and feedbacks were given. Most of the statements regarding the readiness on the assignments fall on the high category. The data of this survey also yielded the similar results presented by Siewert et al. (2011), where 53% of students strongly agreed that the feedbacks were helpful for them to improve their performances. Most of the assignments were creative writings to encourage active learning. The results of this study is in line with the study by Huchting et al. (2020) and highlights the importance of active learning which will help the students to stay interested with the course content and dismantles the status quo of classroom hierarchy. The overall results showed that most of the students agreed on the effectiveness of online learning.

Preference of Face-to face class and Online learning based on the Grades

After analyzing the essays submitted by the first-grade and fourth-grade students, it was observed that the fourth-grade students preferred online leaning and had a more positive opinion about the efficiency of the online education system showing higher average level of freedom in Table 3. It was also found that the first-grade students who did not prefer online leaning found the system more inefficient and reported more negative opinions about it. The views provided by the first- grade students for disliking the online leaning was similar to the study conducted by Bayram et al. (2019) which was basically related to the lack of interaction with teachers, communication with classmates and technical difficulties. In this context, it may be thought that giving preparatory lessons before the online courses are given to the students will have positive results for the students. Nonetheless, it was observed that students' evaluations about online courses are positive regardless of their class level, and the results differ significantly between the groups.Considering the general average, it was found that the students who stated that the online leaning is more suitable decision have a significantly higher average.

To further understand the differences in the opinions from the students from both the grades, an independent t-test was done and the result is shown in Table 3. It was observed that there was significant difference between first grade and fourth grade students based on the responses on face-to-face class [df=8, t=2.615, $p<0.05$], while there was no significant difference between first grade and fourth grade students for their responses on online learning [df=8, t=.387, $p>0.05$]. Taking this result in account, both first and fourth grade students perceived the advantages of online learning with the above-mentioned factors.

Table 3. Preference of face-to-face class and online learning based on the grades

Learning style	Grade	N	Mean	Std. deviation	t	p
Face - to - face					2.615	0.031
	first grade	5	54.8000	39.42334		
	fourth grade	5	8.2000	5.76194		
Online					0.387	0.709
	first grade	5	17.8000	9.09395		
	fourth grade	5	15.6000	8.90505		

Overall analysis of both the questionnaire and essay indicated that the most preferred mode of learning in this pandemic situation for NNIT students could be a blended style of education i.e., both face-to-face and online learning. This view could be a result of their acceptance to current situation to ensure that their education is not disrupted in the future due to the pandemic or any other disturbances.

There were some limitations to this study. The results from this study are based on the self-reported survey data from the students. Firstly, there are possibilities of bias in their responses due to leniency of Japanese students providing inaccurate responses that are socially acceptable. Secondly, the survey was conducted for only one particular English class making it difficult to generalize the outcomes for other subjects. Thirdly, the size of the surveyed students and unequal gender size. Therefore, it is important to interpret the results with caution as it could not be generalizable to different contexts and settings.

CONCLUSION

The results of this study exhibit the positive attitude and overall satisfaction expressed by the students regard to the online learning in NNIT. With this study, it is thought that the readiness of the students will increase the efficiency of online learning environment and its applications.The effective and easy to understand assignment as well as instructions from teachers were the essential factors that affected their satisfaction level.The outcome of this study encourages the use of new technologies for higher education which could improve the teaching and learning environment in NITs. However, the outcomes of this study are case specific and was taken during the pandemic and could not be generalized to other scenarios e.g., post pandemic. Nevertheless, a blended style teaching method with improved ICT skills could be one of the approaches of instruction considering the inevitable post pandemic crisis.Further, more investigations are required for the evaluation of distance learning tools and opportunities.

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CULTIVATING HIGHER-ORDER THINKING SKILLS IN ENGLISH-AS-A-FOREIGN-LANGUAGE TECHNICAL READING INSTRUCTION

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ABSTRACT

"The need to develop critical thinking has never been so vital," said in the 2019 report of World Economy Forum. Additionally, several recent surveys of managers also showed that critical thinking is the number one soft skill that managers feel new graduates are lacking and that education systems have done little to help address the skills shortage. With higher-order thinking skills (HOTS) being ranked among the most in-demand skills for job candidates, engineering education should catch up with the global trend with pedagogical innovation to provide training for cultivating students' HOTS. Although critical thinking has already been listed in the CDIO syllabus under the category of Personal and Professional Skills and Attributes, how to implement HOTS effectively in instruction for engineering students still needs further elaboration. This paper aims at proposing how to cultivate engineering students' higher-order thinking skills in English-as-a-foreign-language (EFL) technical reading instruction and at understanding students' responses to the HOTS implementation. Along with the proposed design of HOTS-based activities, students' awareness, adaptation, and perceived impacts of HOTS are also presented.

KEYWORDS

Higher-order thinking skills, Bloom's Taxonomy, technical reading instruction, Standards: 2, 7, 8

INTRODUCTION

According to the 2018 World Economy Forum report on 2022 required skills, while global industry's needs for memory, verbal, auditory and spatial abilities are decreasing, needs for critical thinking and innovation are increasing and have become indispensable. Unfortunately, traditional pedagogical approaches such as disconnected lectures and factual knowledge based discrete-point assessments have been overemphasizing lower-order thinking skills of remembering and understanding. Students in traditional instruction are often striving to meet the requirements of assessment system which is focused on rote memory with little attention paid to the development of higher-order skills including creativity and critical thinking. Similarly, it can be found that the main focus of most engineering curriculum is still on deductive instruction where lectures are delivered with limited application of the disciplinary content to real life engineering (Narayanan & Adithan, 2015).

Teaching English as a foreign language to engineering students is no exception to innovation for cultivating the 21st century skills. A study by Chou, Jai, and Wang (2020) showed that while interpersonal skills were improved through active learning of Freshman English for engineering students, there was still room for critical thinking skills to be enhanced. According to the authors, "it takes time for students to change learning habits from passively receiving knowledge to actively expressing personal views" (p. 80), especially during the period of adaption to a new learning context of higher education in the freshman year. With this instructional goal of enhancing engineering students' higher-order thinking skills in mind, the Freshman English program for College of Information and Electrical Engineering (IEEFE) was expanded to incorporate higher-order thinking skills (HOTS) and Bloom's Taxonomy as the framework to guide the design of course objectives, activities, and assessment.

LITERATURE REVIEW

Higher Order Thinking Skills

The notion of HOTS, as claimed by Brookhart (2010), is the process of taking stored information in memory and reorganizing and incorporating the information to achieve a purpose in novel situations. Furthermore, HOTS is categorized into 3 basic concepts of transfer, critical thinking, and problem solving. By definition, transfer is the ability for attaining knowledge and skills and applying them to novel situations. Critical thinking skills are mental activities of understanding problems logically, reflective thinking, and making judgments that can guide the development of beliefs and taking action. Lastly, the ability of problem solving is to define problems creatively and find remarkable solutions. Holistically speaking, HOTS can be thought of as a higher-level of cognitive activity which encompasses the abilities: (a) to transfer knowledge and skills in new situations, (b) to define the problem logically and solve the problem creatively, and (c) to argue critically and make a decision.

Undoubtedly, the type of real-world jobs that will exist in the future is hard to predict or non-existent. Achievements at the lower cognitive levels with knowledge and comprehension do not equip students to meet the challenges of this ever-changing world. However, the proportion of questions posed by engineering faculty pertaining to lower-order thinking skills nowadays still outweighs its counterpart, HOTS (Narayanan & Adithan, 2015). Likely, the English teaching methods used in Taiwan provide opportunities mainly with lower-order thinking skills (Chen, 2017). Even if teachers possess pedagogical competence and knowledge to teach HOTS, it is still comparatively more difficult to teach Asian students to do HOTS "because of their collective and hierarchical cultural backgrounds where students rarely challenge what they learned from the teacher (Chen, 2017). Therefore, it is strongly desirable that HOTS should be incorporated in classroom activities such as group discussion, case studies and problem-based learning in order to nurture students' higher order thinking skills (Kusumastuti, Fauziati, & Marmanto, 2019).

Bloom's Revised Taxonomy

HOTS are closely linked to Bloom's Taxonomy. The Taxonomy was originally created by Bloom in 1956 to classify curricular objectives and test items, which was later revised in 2011 by Anderson and Krathwohl with the reason to incorporate new knowledge and thought into the original framework (Anderson & Krathwohl, 2001). Ever since, the Taxonomy has been used worldwide to serve as a pedagogical tool for determining the congruence of educational objectives, activities, and assessment in a course or curriculum (Krathwohl, 2002).

A useful application of the Taxonomy is to combine its knowledge dimension with cognitive dimension to serve as a pedagogical tool for designing question-based activities to teach thinking (Krathwohl, 2002). Teachers can use various ranks of questions appropriately to review, assess learning, and challenge students. As with cognitive processes, questions can also be ranked into cumulative orders. While lower-order questions are those that require students to use lower-order skills such as *remember*, *understand*, and *apply*, higher-order questions refer to those that engage students in manipulating information by using higher-order thinking skills such as *analyze*, *evaluate*, and *create*. In general, lower-order questions are referred to as low cognitive, convergent, or display questions, and high-order questions, on the other hand, pertain to high cognitive, divergent, or referential questions (Bloom, 1956). Anderson and Krathwohl's (2001) defined the six skills as follows:

- *Remember*: retrieving relevant knowledge from long-term memory.
- *Understand*: determining the meaning of instructional messages, including oral, written, and graphic communication.
- *Apply*: carrying out or using a procedure in a given situation.
- *Analyze*: breaking the material into parts and knowing how the parts are related to one another and to the overall structure.
- *Evaluate*: making judgements based on criteria through checking and critiquing.
- *Create*: putting elements together to form a novel and coherent whole.

Moreover, psychological and education research has been placing its emphasis on "helping students become more knowledgeable of and responsible for their own cognition and thinking" ever since the publication of Bloom's Taxonomy (Pintrich, 2002, p.219). To sustain such an educational value, metacognition was added to the original Taxonomy as the 4th type of knowledge, which "involves knowledge about cognition in general, as well as awareness of and knowledge about one's own cognition" (Pintrich, 2002, p.219). Krathwohl (2002) defined four types of knowledge as follows:

- *Factual Knowledge*: The basic elements that the students must know to be acquainted with a discipline or solve problems in it.
- *Conceptual Knowledge*: The interrelationships among the basic elements within a larger structure that enable them to function together.
- *Procedural Knowledge*: How to do something.
- *Metacognitive Knowledge*: Knowledge of cognition in general as well as awareness and knowledge of one's own cognition.

In relation to learning effectiveness, research on metacognition has proven that as students act on their awareness, they tend to learn better (Zhao, Wardeska, McGuire, & Cook, 2014). Nevertheless, metacognitive knowledge is still comparatively overlooked in curriculum or course design in engineering education. Considering that students who know about different cognitive and metacognitive activities for learning, thinking, and problem solving will be more likely to use them, it is thus suggested that teachers strengthen students' awareness of cognitive activities in order for them to appropriately adapt to the ways they think and operate.

METHODOLOGY

The purpose of this study was twofold: (a) to develop and implement a HOTS-based pedagogical procedure in technical reading instruction of the Freshman English program for Information and Electrical Engineering Students, and (b) to investigate students' awareness, adaptation, and perceived impacts of the HOTS-based instruction. This paper reports on data collected during the preliminary stages of planning and implementation with all phases being guided by action research cycle of planning, acting, observing, and reflecting (Pelton, 2010). As a practical research approach to improving teaching and learning, action research emphasizes the teacher's "role as a reflective practitioner who is continually observant, thoughtful, and willing to examine personal actions in the light of the best possible practices" (Pelton, 2010, p. 5). In this study, quantitative approach was employed in data collection by using a self-report survey questionnaire to obtain the students' perceptions of HOTS-based activities of the IEEFE program. As for data analysis, descriptive statistics was used in analyzing questionnaire data to obtain important data characteristics at the initial phase of study, which can serve to inform subsequent refinement of instruction.

Participants

In order to explore students' responses to the HOTS-based Freshman English class design and learning tasks, two Freshman English classes of Automatic Control Engineering and two of Communications Engineering (College of Information and Electrical Engineering, IEEFE) with a total of 115 students, 21 females and 93 males, were surveyed in the final week of Fall semester, 2020. As for the students' English learning experience, most of them started learning English at younger ages: 55 students (47.8%) started at kindergarten, 51 students (44.4%) at lower grades of elementary schools. In terms of English language proficiency as measure by Oxford Online Placement Test (OOPT), near three quarters of the students (73.9%) were at or below CEFR B1 (Common European Framework of Reference for Languages). Moreover, 26.1% of the students had heard about HOTS before and about 25% of the students had experienced HOTS-based activities.

The HOTS-based Technical Reading Instruction of IEEFE

The dual goals of Freshman English program for College of Information and Electric Engineering (IEEFE) are: (a) the development of personal skills and attributes as delineated in the CDIO syllabus, and (b) the enhancement of technical reading comprehension in English. In Phase 1 of the IEEFE program from year 2017 to 2019, interpersonal skills and active learning were the primary goals which have been satisfactorily achieved (Chou, Jai, & Wang, 2020). To enlarge the fruitful outcomes of IEEFE, higher-order thinking skills were added to the program goals in year 2020. Unlike in Phase 1 where oral and written presentations in English were highlighted in the course objectives, assessments in Phase 2 focused more on students' ability to think critically and to solve problems creatively.

Out of the two weekly sessions which lasted for 15 weeks, one of the sessions was devoted to technical reading in English with the reading material being compiled by Chairs of the collaborative departments of College of Information and Electrical Engineering. Topics of the reading texts were related to the latest development of technology such as autonomous driving, AI, and virus-killing masks. A main reason for the selected topics were to increase engineering students' interest in reading in English. In addition to teaching the reading texts, the IEEFE instructor's responsibility was to train students' reading strategies and higher-order skills by ways of question-and-answer strategies such as reading notes, group discussion, and group or individual question-and-answer worksheets. Teacher questioning technique was used to review, examine learning, and challenge students to do higher-order thinking. By answering the teacher's questions, students were provided opportunities to construct meaning, solve problems, find answers, and find information. The design of questions before, during, and after the technical reading instruction was particularly crucial for activating students' thinking skills and strengthening reading comprehension as well. Therefore, questions of the cumulative categories of Bloom's Taxonomy incorporated with types of knowledge (Krathwohl, 2002) were posed at different stages of reading instruction for different purposes.

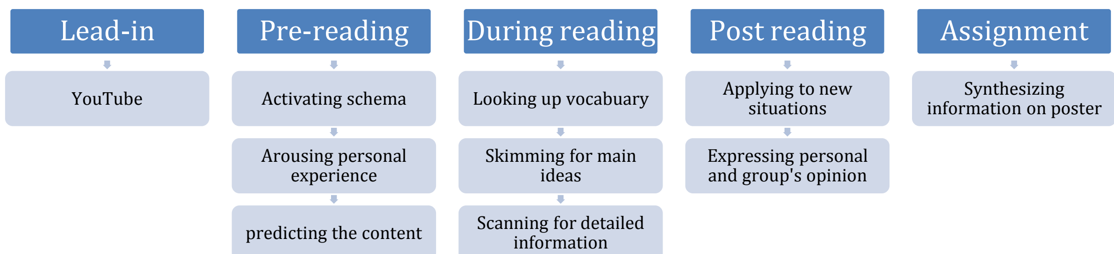

Figure 1. Purposes of questions of the reading instruction

At the Lead-in stage (Figure 1), taking the topic of *Driverless Cars* as an example, a YouTube film entitled *Salto: The cute jumping robot that opens the door for cyborg ninjas* was played to activate interest in the topic. Afterwards, two lower-order questions which combine *factual knowledge* with *understand* of Bloom's Taxonomy were posed as followed:

- *What does SALTO stand for?*
- *Why is it important to invent a jumping robot?*

As a pre-reading activity, a question: "*Without consulting the article, try to think of 3 adjectives that closely describe the jumping robot and 3 verbs that you think the robot can do"* was posed to elicit students' creative ideas and predictions on the topic. Later, at the *during reading* stage, a lower-level question in relation to Bloom's category of *understand*, "*What has Salto been improving in terms of capabilities?*" was asked to encourage scanning strategy for information to ensure reading comprehension. Finally, at the post reading stage, a higher-order question which belongs to *evaluate* and *create* of Bloom's Taxonomy was posed for students to explore beyond the topic and to communicate personal views. An example of this type of question is: *What is the future use of jumping robots?* As the unit group project, the students were asked to produce a poster (Figure 2) collaboratively on *Salto*. Having exemplified different levels of questions suitable for gradual steps of technical reading instruction, it is important to mention that various levels of cognitive strategies should be embedded within the usual content-driven lessons. Teachers can teach various levels of thinking skills and cognitive processes as they teach other content knowledge to enlarge students' repertoire of cognitive skills for facing different learning tasks (Pintrich, 2002). Thus, different cognitive processes of Bloom's Taxonomy are explicitly labelled and made known to the students throughout the stages of reading instruction of IEEFE to raise their awareness of both LOTS and HOTS strategies.

Figure 2. Student Project: Poster on Robot SALTO

Measure and Procedure

Following a semester's implementation of HOTS in the technical reading instruction, a survey questionnaire entitled *Engineering Students' Awareness and Adaptation of HOTS in IEEFE Technical Reading Instruction* was designed by the researchers to collect a general overview of students' perceptions of the design and implementation of HOTS-based activities. The questionnaire consisted of 48 statements based on five-point Likert scales (from *strongly disagree* to *strongly agree*). There are four parts to the questionnaire, which were: (a) background information on gender and English proficiency score obtained from Oxford Online Placement Test (OOPT), (b) awareness of HOTS-based activity design, (c) awareness of cognitive processes, (d) adaption of HOTS-based learning, and (d) perceptions of impacts of HOTS-based activities. Since concepts of thinking levels might be abstract to some students, examples of thinking activities were added to the awareness-related questions to make them more concrete. The questionnaire was administered in the final week of fall semester of 2020. In principle, descriptive statistics was used to obtain a preliminary understanding about the students' perceptions and to gain an overall view of relationships among the variables.

RESULTS AND DISCUSSION

Awareness of HOTS-based Activity Design

As aforementioned, students who act on awareness tend to learn better (Zhao et al., 2014). Accordingly, the teacher would inform the students of the level of thinking skills at the beginning of each activity to raise students' awareness of HOTS. In this study, the survey yielded satisfactory results on awareness of HOTS with item mean scores ranging from 3.79 to 4.47. First of all, the students noticed that the instructional design was different from that of the high school English course (M = 4.37, SD = .87). As for allotted class time, the students perceived that the time lengths for questioning and answering (M = 4.47, SD = .68), for looking for answers (M = 3.97, SD = .81), and for group discussion (M = 3.79, SD = .84) were all greater than that of teacher lecture. Moreover, with regard to types of questions, the students noted that the questions were at both lower and higher levels and of various cognitive categories (M = 3.92, SD = .82). A finding drawn from these *results* indicated that the students were aware that: (a) the HOTS-based activity design was different from the kind of traditional English instruction that they had experienced prior to college, (b) more class time was allotted for group discussions and HOTS activities, and (c) teacher's questions were intended to include both lower and higher orders of thinking skills. Considering that students who act on awareness tend to learn better (Zhao et al., 2014), it is thus suggested that the design of HOTS-based instruction should be introduced explicitly in order to strengthen subsequent HOTS development.

Awareness of Cognitive Processes in Class Activities

According to Zhao et al. (2014), students who know about different cognitive and metacognitive activities for learning, thinking, and problem solving will be more likely to use them. Therefore, the technical reading activities of IEEFE were designed by means of a combination of knowledge dimension and cognitive process of the Bloom's Taxonomy to ensure the depth and breadth of cognitive processes. The results on awareness of cognitive processes showed that all item means were above 4.15, and all categories of Bloom's cognitive processes were equally perceived by the students. Of all categories of cognitive processes, the students were particularly aware of questions which required: application of life experience (*M* = 4.46, SD = .65), discussion of personal thoughts about a point (*M* = 4.33, *SD* = .69), and synthesis of information from the text and give a presentation (*M* = 4.3, *SD* = .69). These results may imply that the students spent more time on the HOTS tasks and therefore were more impressed by them. Such a finding may indicate that not only that the students experienced different categories of cognitive processes in the class, they were also able to distinguish tasks which required lower and higher levels of thinking skills.

Adaption of HOTS-based Learning

Changes in instruction may bring about undesirable chaos if students are unaccustomed or even opposing to them (Kusumastuti, Fauziati, & Marmanto, 2019). Hence, for any program or course innovation, it is of little use without students' willingness to adapt to the change. Having been introduced to and experiencing HOTS activities, the IEEFE students expressed that they had been accustomed to the question-based instruction and that they had adapted to be evaluated formatively by how they answered higher-order questions in the class. The survey result on adaption of HOTS-based learning showed that the students had adapted to question-based activities (*M* = 4.13, *SD* = .8). In particular, they were used to student-centered instruction which allowed them to decide the most appropriate meanings for English vocabulary based on their own understanding of the technical reading (*M* = 4.25, *SD* = .85). In addition, it also showed that the students were able to cultivate active learning habits by engaging in activities which asked them to: (a) solve problems by applying their own life experience (*M* = 4.11, *SD* = .87), (b) express personal thoughts about a point in a text (*M* = 4.09, *SD* = .84), and (c) to elaborate on the rationale of the response (*M* = 4.09, *SD* = .89). Such findings are especially valuable for Taiwanese students who rarely challenge what they learn from the teacher (Chen, 2017) and who have been accustomed to passive and test-driven learning in traditional teacher-centered education.

Perceptions of Impacts of HOTS-based Activities

The next phase of the present study, in addition to exploring students' awareness of and adaptation to HOTS-based instruction, was to explore how they perceived the impact of HOTS activities. Although they only experienced a semester of HOTS activities, the students still expressed relatively positive perceptions of HOTS in technical reading instruction. They responded positively to impacts of HOTS on skills of communication (*M* = 3.90, *SD* = .91), problem solving (*M* = 3.87, *SD* = .90), and creativity (*M* = 3.86, *SD* = .94). In addition, they also considered HOTS activities helpful to enhance focal attention to class learning. Such results can be interpreted that the students had positive perceptions of HOTS activities. They also affirmed the effectiveness the HOTS approach incorporated in technical reading instruction for cultivating their higher order thinking skills.

Despite its positive responses, the results on impacts of HOTS also raise some concerns. In comparison with the mean scores of the previous sections, the item means of this section were relatively lower. Such a finding may imply certain limitations of HOTS implementation in English reading instruction. First, students' English language skills can be discouraging to the students during reading comprehension and communication in English. On average, near 75% of the students were at the elementary and intermediate levels of English proficiency as measure by *Oxford Online Placement Test*. As English-as-a-foreign-language students, the students' struggles in comprehending the reading materials, thinking critically, and expressing ideas orally and in writing in English on the reading topics may become an obstacle in conducting HOTS, which may have consequently impeded motivation and active engagement in activities. Second, unlike traditional EFL reading instruction in which students may respond passively to the teacher's explanations of vocabulary and grammar, HOTS-based activities require students to actively engage in the tasks by understanding the reading material first and then collaborating, discussing, thinking, and creating answers to teacher's questions. It can be sure that higher-order activities can be more time-consuming than lower-order activities especially for EFL students, primarily due to the fact that HOTS is more cognitively challenging and requires more student effort. As a result, class time may not always be sufficient to complete the HOTS-based procedure, which in turns may have deterred the students from being fully benefited from the teaching tasks.

CONCLUSION

The present study aimed primarily to develop a technical reading instruction model which incorporated the use of HOTS tasks to cultivate students' higher-order thinking skills in addition to English reading comprehension and communication. To gain a preliminary view of the effectiveness of HOTS implementation in IEEFE, this study was conducted to examine students' awareness, adaptation, and perceived impacts of teaching technical reading with HOTS. Findings of this study were inspiring for those who plan to implement HOTS-based activities in the classroom. Nevertheless, a limitation of this study is that the HOTS-based instruction was not long enough for the students to fully understand, adapt and benefit from it. Major findings of this study are summarized below.

First, the students were able to perceive about the HOTS-based activity design and cognitive processes, which was different from that of their high school English classes. This finding helps reinforce the necessity of introducing cognitive processes explicitly in classroom practices (Zhao et al, 2014). Second, the students expressed that they had been able to adapt to different levels of cognitive processes ranging from lower order to higher order thinking skills. Such a finding was particularly encouraging in that, albeit their accustomed passive learning habits in the traditional exam-oriented education system, the students were still able to develop a positive attitude towards HOTS. Last, the students responded positively to the impacts of HOTS on communication, creativity, and problem-solving skills. Specifically speaking, teachers should design classroom activities and assessments which encourage and challenge students to analyze, evaluate and create new information based on the acquired knowledge. Findings of this study may open a door to future incorporation of HOTS to meet the CDIO Standard 7, integrated learning experiences, and Standard 8, active learning. With regards to CDIO syllabus goals of personal skills and attributes, this study inspires engineering educators who strive to cultivate students' creative and critical thinking (CDIO Syllabus Items 2.4.3 and 2.4.4) and communication in English (Item 3.3.1) in the class.

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DESIGN EXERCISE STRATEGY FOR LOCUS OF CONTROL AND SELF-EFFICACY

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ABSTRACT

In the past years, there has been an interest to map and characterize the architectural engineering and the lighting design programs at the School of Engineering, Jönköping, Sweden. The investigations revealed issues related to student's self-efficacy and locus of control. This study aimed to create a routine for solving design problems by planning a small individual design exercise as a mental reward mechanism for students to boost their self-efficacy and internal locus of control. It was hypothesized that internal locus of control correlates to an increased self-efficacy level. The study objectives were (1) to propose an interior design exercise on problem-oriented learning that fits in the overall curriculum of Architectural engineering and Lighting design programs at the undergraduate level. Also, (2) to assess students' locus of control and status of individual preference for problem-solving approaches and self-efficacy. The interior design exercise lasted for a month in February 2020. With the outbreak of the COVID-19, the interior design exercise was the only design exercise held. Altogether, sixteen students completed the workshop. The pre- and post-evaluations show that a single design exercise had slightly shifted the students' locus of control to more internal, which indicates a more self-controlling behaviour. Also, an increase in the enjoyment of a design exercise was recorded, and students demonstrated a slight preference shift towards a less defined and more open design exercise. Students' internal locus of control correlated to self-efficacy measures in the pre-intervention phase but only showed a tendency in post-intervention. The design workshop teacher's reflection on the participants' design process revealed that many worked in groups, which might decrease the self-oriented decision-making rating for self-efficacy. The future investigation would extend these design workshops' complexity by involving a set of lighting design, architectural and urban space design exercises for a more comprehensive review of the effects.

KEYWORDS

locus of control, self-efficacy, design workshop, active learning, engineering education research, Standards: 5

INTRODUCTION

In the past three years, the investigation and mapping of the group design exercises at the School of Engineering at Jönköping University (Fischl, Granath, & Bremner, 2018; Fischl & Wänström-Lindh, 2020) had established a sense of urgency for examining the students' affinity to deal with design problems. Studies generated a powerful guiding coalition and vision for developing strategy and empowerment for faculty members to implement a design process.
In the beginning, it was assumed that an architectural design problem could be more successfully approached and completed when the students' locus of control is more internally

driven and the design problem is less prescribed. These investigations' original hypothesis was to prove an architecture-engineering design method capable of transforming undergraduate design learners' mental resources to deal with *wicked problems* (Rittel and Webber, 1973). In line with this, the current investigation follows Kottler's (1995) recommendation about establishing organizational and people's attitude change toward an architecture-engineering problem-solving process. The entire process is conceived by the CDIO approach (Crawley, Malmqvist, Ostlund, Brodeur, & Edström, 2014, p.35) to promote deep learning and conceptual understanding for student motivation and their interpersonal skills in the culture of experimentation and critical and creative thinking. Therefore, a generic design process was formulated over recent years to accommodate the new requirements. This paper focuses on the next stage of change management, namely, introducing small mental rewards for teachers and students in multidisciplinary design projects. Consequently, this study aimed to create a method for solving design problems by planning a small individual design exercise as a mental reward mechanism for students to boost their internal locus of control and self-efficacy.

The locus of control (LOC) is a personality trait that refers to a perception of events happening to an individual. The outcome of events can be either internally instructed by behavior or externally by fate, luck, or other conditions. Its origin is in the Social Learning Theory (e.g., Kormanik & Rocco, 2009), which posits "*that an individual's actions are predicted on the basis of the individual's expectations for reinforcement, the perceived value of the reinforcement, and the situation in which the individual finds himself or herself*" (p. 466). Consequently, when university students receive reinforcement, and their situation matches their expectancy, their self-efficacy is boosted. The positive reinforcement would build up a mental reward system that avoids adverse outcomes, and therefore the experience of the event can be appreciated. On the contrary, when events are negatively appraised, a stress reaction is generated, heightening arousal and giving rise to the flight response to avoid fear. To measure locus of control and refer to the personality trait mentioned above, Rotter (1966) has developed a widely used tool. The dimensions (internal vs external) of locus of control were compared in many studies among college and university students on academic performance (e.g., Kirkpatrick, Stant, Downes and Gaither, 2008), self-esteem (e.g., Sadaat, Ghasemzadeh, Karami, Soleimani, 2012) and self-efficacy (e.g., Carifio & Rhodes, 2002).

Self-efficacy is also derived from the Social Learning Theory, and as Bandura (1977) explains, "Stressful situations generally elicit emotional arousal that, depending on the circumstances, might have informative value concerning personal competency. Therefore, emotional arousal is a constituent source of information that can affect perceived self-efficacy in coping with stressful situations" (p. 289). The difference between locus of control and the self-efficacy measure can be characterized by the notion that the former measures affect the individual's societal level as it forms the individual. At the same time, the latter finds stimuli-response beliefs in the individual's proximity which are related to personal skills in achieving a task by the management of emotional arousal. Sagone & De Caroli (2014) suggested a comprehensive measurement for the self-efficacy scale to explore the perceived self-efficacy in an academic context based on 30 items with 7-point Likert scale. This scale consisted of four factors, obtained by means of factorial analysis with principal components method: self-engagement, self-oriented decision making, others-oriented problem solving, and interpersonal climate.

When connecting the Social Learning Theory through the locus of control and self-efficacy measures to Kottler's recommendation, one might see the similarity in how the practicality of the small winnings (Stage 6) is related to a rewarding behaviour is hypothesized for delivering a positive organizational change. Subsequently, this study's original aim was to create a routine for solving design problems by planning a set of small individual design exercises as a mental reward mechanism for students to boost their self-efficacy and internal locus of control. Due to the outbreak of the COVID-19 and the sudden change in the education routines, the planning of the four extra-curriculum workshops stopped. Only the first workshop was held. Therefore, the study's aim was modified accordingly. A single workshop aims to create a design exercise experience as a mental reward mechanism for students to boost their self-efficacy and internal locus of control. It was hypothesized that internal LOC is positively correlating to higher self-efficacy measures.

METHOD

Mainly a quantitative investigation was performed in this study by administering an internet-based questionnaire on demographics, locus of control, and self-efficacy. Reflection of the design workshop teacher was also collected concerning the locus of control and self-efficacy measures.

Participants

Initially, 33 students signed up for the interior design workshop, but many failed to complete the requirements, including filling out the questionnaires and completing the design task. Altogether, this study included 16 architecture-engineering students (M_{age}=23,87, SD_{age}=3,364), out of which ten attended the third year. The demographics of these participants are shown in Table 1. Participation was announced in each year and subject major simultaneously, and it was emphasized that this workshop is an extra curriculum activity and highly valuable for developing a personal portfolio.

Table 1. Demographics of the participants

	Year 1	Year 2	Year 3	Total
Age (SD)	21.33 (1,52)	22.00 (2.64)	25.20 (3.39)	23.87 (3.36)
Number of Participants (M, F)	3 (2, 1)	3 (1, 2)	10 (4, 6)	16 (7, 9)

Note: SD=Standard Deviation, M=Male, F=Female

Data collection instruments

An internet-based questionnaire was administered pre- and post-intervention. In the first part, demographic data (age, gender), academic subject major, and the research consent for participation and publication of results were recorded. Subsequent data were collected on individuals' locus of control (Nowicki-Strickland, 1973). The repeated measures entailed 40 standardized items on a forced-choice category level (Yes, No), resulting in a single Locus of control (LOC) ratio value. The lower LOC value indicated a more internal, while the higher LOC value, a more external position of control.

The next part of the online survey collected information about individual learning styles. This instrument is under consistent development by the primary author, and earlier versions are published in international CDIO proceedings in 2018 and 2020. It was designed to capture individual differences regarding the preference and earlier experience of assignments-oriented and problem-oriented design exercises. The former intended that the design exercise is well defined, and students are not allowed to challenge it; meanwhile, the latter entailed an open exploration of a problem. The ratings were indicated on a seven-point Likert-scale (1=Undefined project (problem-oriented) to 7=Defined project (assignment-oriented)).

The final part of the online questionnaire portrayed an academic self-efficacy scale (Sagone & De Caroli, 2014) which consisted of 28 items on an adapted 6-point Likert-scale (1=Not at all possible to 6=Completely possible) along with four self-efficacy factors: self-engagement, self-oriented decision making, others-oriented problem solving, and interpersonal climate. The first factor refers to the ability to overcome difficulties with personal contribution, while the second factor refers to the ability to solve problems using personal resources. The third factor refers to the ability to solve critical issues using other people resources, and finally, the fourth factor is measuring a prosocial and collaborative climate in interpersonal relationships.

The interior design workshop objective was to create a new and improved space lobby and adjacent general spaces for the School of Engineering students, Jönköping. The students could choose their preferred technique and medium for presenting their conceptual work. The workshop teacher suggested the design task and reflected on the students' process after the four-week workshop.

Procedure

A four-months extra-curricular workshop was originally planned following the previous investigation by Fischl & Wänström-Lindh (2020). The notion was to introduce small mental rewards for teachers and students in the form of multidisciplinary design projects and is positioned so that all workshops should propagate internal control and enhancing self-efficacy within the more and more undefined (problem-oriented) design projects. Therefore, a series of workshops aimed to be presented to students each month, between February and May 2020. Out of these four workshops, only the interior design workshop was held and completed. Students were administered a pre- and post-intervention questionnaire online, including LOC and self-efficacy questionnaire, questions on enjoyment of a design assignment, and a preferred learning style for a design exercise. After successfully completing the questionnaires and the interior-design project delivery, the student received a diploma for participation. The reflection of the faculty member in charge of the workshop was also collected.

Data Analysis

Locus of control (LOC) scores were gathered pre- and post-intervention, calculated by the Nowicki-Strickland questionnaire (1973) on interval data. Gender was treated as nominal, age as ratio, and school year as interval data. Graphical analysis was performed on the limited dataset, gender and age differences could not be explored. The individual plot-diagram depicting pre- and post-intervention LOC and preferred learning style (Undefined-Defined) measures were categorized into activity quadrants. These quadrants are the results of development over the past years (Fischl *et al.*, 2018, Fischl and Wännström-Lidh, 2020), in which students LOC and affinity for preferred learning styles were categorized:
- Comfortable: students are receiving adequate external demands and external support for completing a defined task.
- Uncomfortable: students are experiencing an undefined task; however, the external support is not arriving for dealing with the complexity, and their level of helplessness is exposed.
- Performative: students are internally driven, routine-oriented, and familiar with the demands of the defined task.
- Creative: this quadrant is sought after; it combines internal control with preference to undefined tasks.

Additionally, to LOC and learning styles graphical analysis, a Pearson correlation was performed to investigate the relationship between LOC and the self-efficacy factors. It was hypothesized that internal LOC has a positive correlation to self-efficacy factors. Although a paired sample t-test for differences was also performed, it did not return with significant results. The reflection of the workshop teacher was treated as complementary information in a narrative form. It was aimed to enrich the result and discussion sections of this paper.

RESULTS

This paper aimed to investigate the effects of a design workshop in terms of students' locus of control, preferred learning styles (undefined-defined task), and self-efficacy. It was hypothesized that a small design workshop promotes reward mechanism and boosts students' self-efficacy and internal locus of control as well as reposition the learning styles to a more undefined preference. Figure 1 summarizes the findings pre- and post-design intervention regarding learning styles and locus of control.

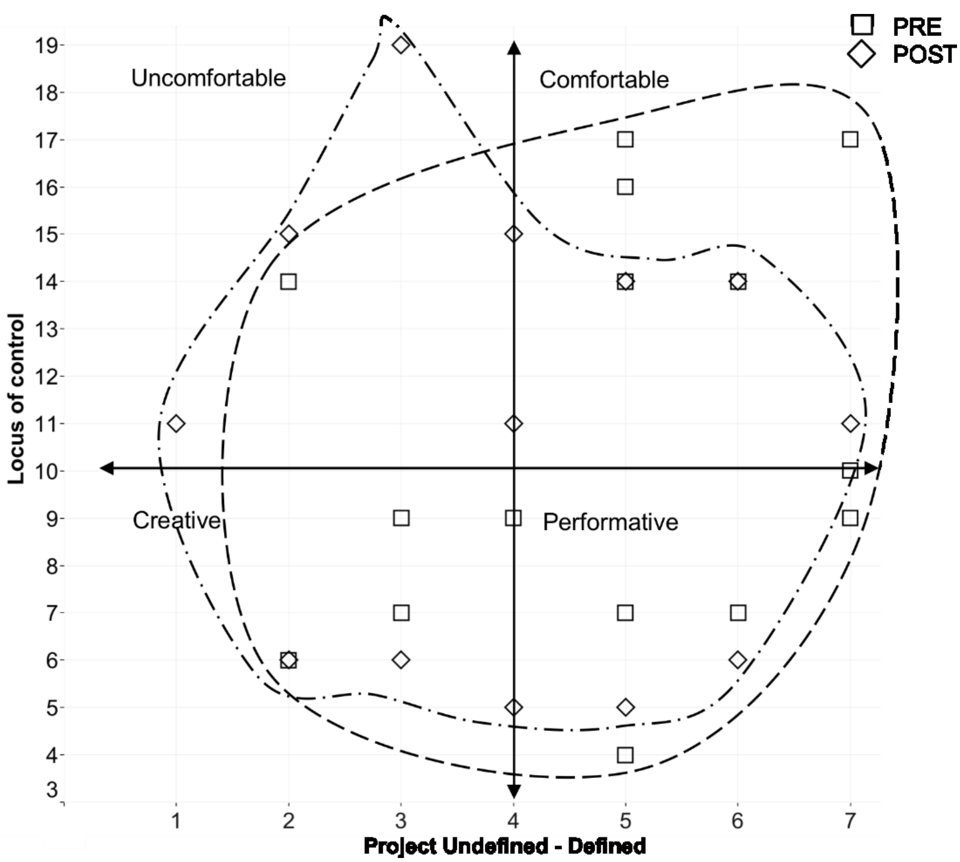

Figure 1. Pre- and post-intervention positions for students' LOC and preferred project definition (N=16). Note: The LOC neutral position is located at the mean level of LOC=10 (LOC<10 more internal, LOC>10 more external). The project definition axis is at a neutral position by 4 due to its 7-point scale (1=More undefined to 7=More defined).

This plot diagram is less sensitive to represent minor changes after the intervention. In Table 2, the mean and standard deviation of the measured variables are presented pre- and post-intervention. It is remarkable that after the design workshop, the learning style preference shifted to a less defined status, the enjoyment in a design task increased, while the locus of control value decreased, which indicated a less external control need. As for the factors in self-efficacy, slight changes could only be detected. Significant correlations were found between LOC pre-intervention levels and three out of four self-efficacy pre-intervention factors (self-engagement (r=-.501, p<.05), self-oriented decision making (r=-.606, p<.05), others-oriented problem solving (r=-.719, p<.01)). These results indicate that the higher the LOC (more external), the lower the self-efficacy, which fails to reject the hypothesis (internal LOC positively correlates to self-efficacy). The results were not significant for the post-intervention correlation between the LOC and self-efficacy factors but kept supporting the hypothesis.

Table 2. Summary of Mean and SD are reported in pre- and post-intervention (N=16).

	Pre-intervention		Post-intervention	
	Mean	SD	Mean	SD
♦Learning style preference	4.38	1.500	4.19	1.682
♦Enjoying a design task	5.88	.885	6.06	.929
♠Locus of control	10.44	4.242	10.06	4.449
♣Self-engagement	4.77	.688	4.74	.645
♣Self-oriented decision making	4.68	.580	4.58	.648
♣Others-oriented problem solving	4.15	.608	4.39	.997
♣Interpersonal climate	4.98	.571	5.00	.548

Note: ♦The ratings were on a 7-point Likert-scale. ♠The ratings were on a category scale and combined into a ratio. ♣ The ratings were on 6-point Likert-scale.

Reflection: At the beginning of the first week, an introductory agenda was presented with a short description of the stages within the design process, conceptual, schematic, and design development. Through self-engagement, the students were encouraged to start with analyzing the lobby space, find problems, and start conceptualizing and problem-solving to come up with one solution that would be developed and presented with drawings, mood boards, and renderings at the end of the workshop. After the introduction, most students looked for more instruction from a teacher showing signs of uncertainty and inability to perform the task. With intentionally little or no guidance to the problem-solving process, many participants could not continue and dropped out of the workshop.

Students were driven by different self-motivation to continue where some were able to develop on their own and see what their potentials were with little or no tutoring. Others were inspired to complete the project and task motivated by their goals to receive a diploma and reward for completing the workshop. The remainder of the participants were struggling with the idea of individual self-performance and questioned their problem-solving ability. These different groups needed tutoring on separate levels. The first group was looking for very little tutoring and did not question their design and problem-solving skills. The second group was more performance and reward-driven and needed more assistance in accomplishing the task. The third group seemed lost in the idea that they were asked to study, analyze, and solve the problem on their own as well as working within a more openly defined project. They were looking for someone else to give them one right solution and were the least internally driven and were falling behind on the progression of the task at hand.

Throughout the month, the students were encouraged to follow the design process in coherence with the agenda. We met once a week and during the second-week meeting. I noticed a distinct difference in the divergent performance levels. An aggressive timeline and agenda showed that by the second week, the students were to work on schematic designs with options for problem-solving. Those who followed their own self-oriented internal problem skills and interpersonal cooperation with fellow students and tutors showed more creativity and better solutions.

As we met during the third week, students worked on the design development and discussed work in progress and options for their solutions and problem-solving. My observation was that the students who had been engaged from the beginning with a focus on their self-assured abilities to solve a problem and with little tutoring help showed the most creative options.

The other individuals who also did well at this point were the few who had gotten past their doubts of being able to internally solve a problem and not being taught the solution. Their newly discovered skills within themselves brought out a sense of belief and confidence in their own actions, behavior, and thought process. Finally. in the fourth week, sixteen students of thirty-three who had initially signed up presented their work.

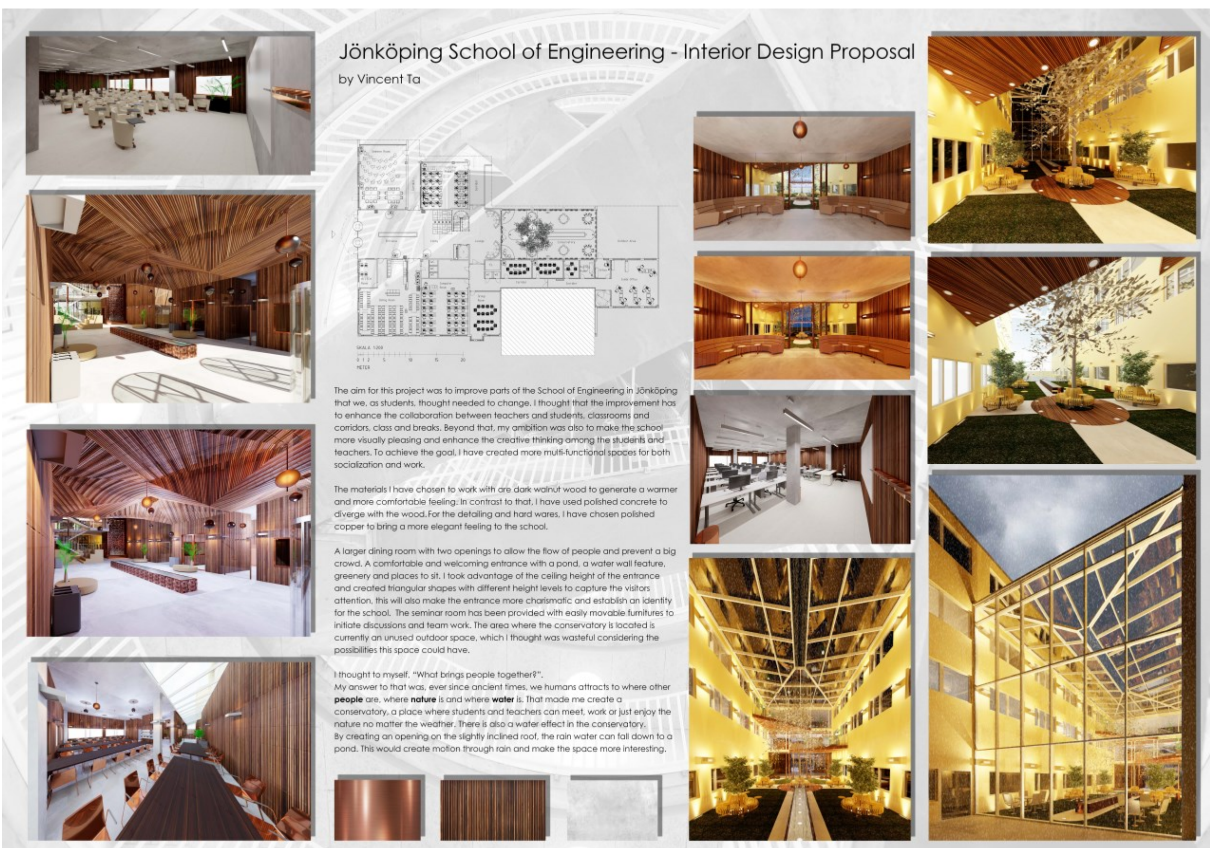

Figure 2. A result of the design workshop by Vincent Ta (a third-year student).

DISCUSSION

The initial goal was to introduce small design challenges for students, but it had been compromised by the coronavirus pandemic. Consequently, the aim became to create a design exercise experience as a mental reward mechanism for students to boost their self-efficacy and internal locus of control. It was hypothesized that internal LOC is positively correlating to higher self-efficacy measures.

The prerequisite for successfully completing the workshop and being reported in this study was administering the pre- and post-intervention questionnaire. A decrease in participants was partially due to this requirement. Another contribution might be that students' misjudgment of time and individual resources to complete an extra-colloquium besides the general school loading. Furthermore, students might not fully comprehend that the design workshop was part of a study and not a faculty charity. Therefore, those who did not comply with the introduced measures were excluded from this study and failed to receive the extra-colloquium certificate. The pre-intervention LOC indicated that the students were used to more prescribed assignments, requiring more input from the workshop teacher. The post-intervention measures of learning style moved to a less-prescribed position but stayed relatively central. This incremental change is still preferable, along with the decrease in LOC externality. The post-intervention measures of LOC and self-efficacy factors did not show a significant correlation, and even the self-oriented decision-making factor decreased. An explanation for this decrease could be that students worked in groups rather than individually as it was introduced. Consequently, the part of the self-oriented decision-making skill is likely to suffer from the lack of independent decision making. Unfortunately, the online survey did not register which students worked together, and how many were in a group. According to the workshop teacher's notes, three groups with two members each were identified, and their answer might have been the cause of this result.

The measurement methods employed here were partially untested. The self-efficacy measures were not gathered through focus group interviews, but a novel measurement scale adapted to this study. The original measures for the sub-factors used factorial analysis to identify the items belonging to each self-efficacy factor. The self-efficacy measures, however, were showing rating similarities across its sub-factors. The adoption of a questionnaire-based self-efficacy measure proved to be less time consuming than the qualitative evaluations applied in the previous studies within the same architectural engineering program.

Learning style ratings on a scale from a defined project to undefined seemed to be an effective tool to describe the preference variation from an assignment-based to a project-based orientation. Students traditionally requiring a lot of support from the teachers when completing an assignment-based project; meanwhile, the more open project-based design exercises are fostering creativity and contribute to an increase in self-efficacy.

One of this study's limitation entails the number of participants successfully completing the design exercise, which needs to be addressed in the forthcoming design workshops. A clear instruction may help to avoid the overestimation of one's strength in participation. When a participant is completing the prerequisites, the online measurement instruments need to be optimized for detailed tracking of group making and various decision-making regarding alteration of the project outlines.

CONCLUSION

This paper strengthened the assumption that a small design workshop promoted students' self-efficacy and internal locus of control and learning styles to a more undefined preference. Furthermore, this activity increased the level of enjoyment with a design workshop. The hypothesis regarding a more internal LOC would contribute to higher self-efficacy proved right at the pre-intervention phase. Future investigation should entail a larger sample of participants and a more comprehensive design exercise battery that follows individual and group decision-making processes. The measurement instrument on LOC, self-efficacy, and learning styles seems still relevant for the architectural engineering domain's characterization.

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FROM DIGITALIZED EDUCATION TO COVID-19 RESTRICTED EDUCATION: CHALLENGES AND DIFFERENCES

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ABSTRACT

At the department of Information technologies at Åbo Akademi University, the digitalization of education was being performed with the objective of being able to give higher quality education to an increasing number of students but using the same level of teaching personnel resources. In this work, several actions were performed, such as recording lectures and editing recorded lectures, testing out different systems for automatic grading of exercises, different formats of giving the lectures themselves (such as a flipped classroom). When almost a year of these activities had been performed, the COVID-19 crisis forced a fast change in how teaching was being done at universities all over the world. This paper analysis, with the support of a survey and interview performed, how the transformation to 100% online teaching was performed, knowing that a lot of efforts had been made earlier to digitalize the education. The paper explains the challenges still remaining and analyzes the feasibility of totally remote education. We analyze the difference between a digitalized education and a COVID-19 restricted education, regarding teaching and student motivation, tools being used, dropout rates, and communication issues. The papers also give conclusions on things that both worked well and did not work well in this transformation.

KEYWORDS

Digitalization, COVID-19, Automated assessment, Communication, Student interaction, Virtualization, Standards: 3, 5, 6, 8, 10, 11

INTRODUCTION

The department of information technologies (IT) at Åbo Akademi University in Finland is a rather small educational unit, with a faculty size of approximately 15 teachers, and the number of freshmen students is currently around 60 per year. Additionally, around 20 master level students start their studies every year, mostly foreign students. Åbo Akademi is a Swedish-speaking university in Finland, with four faculties, providing education in humanities, pedagogy, social sciences, economy, natural sciences, and technology. The IT department gives education in natural sciences (computer science) and technology (computer engineering).

The faculty of natural sciences and technology has for long been struggling with an economical deficiency, which has led to a rather defensive faculty recruitment policy, i.e., no new teaching resources. At the same time, the interest in IT studies has become very solid in the department, meaning that we need to give more education, with the same size of faculty. This led to a strategy of strong digitalization development process at the department, where we did development of courses aiming to remove straightforward repetitive tasks in the education, freeing up resources to tasks that the faculty finds more valuable. Correction of exercises was one task that was automated through different tools like CodeGrade integrated into Moodle. The teachers can instead use the time previously used for grading, for more planning of common classes and for discussions with the students, i.e., perform more qualitative work instead if quantitative work. We also did on-line teaching and video recordings of most of the lectures, to have them available off-site and also for later viewing.

The work on digitalization at the department of IT was analyzed in an earlier paper by Björkqvist and Roslöf (2020), where the main conclusion was that the digitalization efforts made it possible to enable more interaction with the students during the classes, to increase the level of positive learning activities. This paper was due to be published in the CDIO 2020 conference in Bangkok, but that conference was cancelled due to the COVID-19 pandemic (the paper was however published in in the on-line version of the conference). Instead, as we all in the educational field know, there was an overnight transformation to online education in almost all educational levels. That meant that the educational sector globally was forced to take a giant step forward into digitalization. In Europe, 85% of classes were transformed to online, 12 % where suspended, and 3% where cancelled (Marione et.al. 2020). So, one of the main questions in this paper is – what was the advantage of doing these digitalization efforts prior to the pandemic? Could we just go on as business as usual, utilizing the digitalization efforts already done?

You should never waste a good crisis is a citation from Winston Churchill. As Zhao (2020) argues, the COVID-19 pandemic either forced or made it possible to rethink the *what, how and where* of education. The *where* was definitely changed, as schools and universities were closed down. The *what* might have stayed quite the same, but *how* was very much moved from classroom lectures to on-line lectures.

In this paper we address the differences and challenges when going from digitalized education to pandemic restricted education. Which components of education did just go on as previously, and which components are rather different now?

BACKGROUND

The way the Higher Education Institutes (HEI) practice their education needs continuous development. The society around us changes, the technology around us changes. Today we have access to almost all the information there is globally available from our home sofa. This has changed massively in the last 20 years, and the question is how the HEI education has adopted this.

In the international Delphi survey on the future of learning and Higher Education (Ehlers and Kellermann, 2019), the Delphi resulted in hallmark indications on the shift from academic education and teaching to active learning and autonomy. This learning experience is fundamentally different from the model of today. This future learning comprises (1) structural aspects, where learning can be much more spread than today, and (2) the pedagogical design of academic learning. The pedagogical design comprises aspects such practices of assessment, peer-validation, focus on futures skills, learning communities, and interactive socio-constructive learning environments. The experts in the survey believe that changes to academic learning design come before structural changes. Hence, the *how* and *what* we learn will change more than *where* we learn it.

Especially the emerging focus on future skills change the higher education. Instead of having the narrow focus on learning correct answers to known questions, the future skills mean autonomous learning, self-organization, creativity, and innovation. Students can in the future also build personalized curriculums, interacting with teachers/professors. The future skills mean the ability to perform complex problem solving, dealing with uncertainty, and developing a sense of responsibility. This would go beyond the current emphasis on knowledge acquisition and studying based on a defined curriculum.

In the online article Rowe (2016) discusses the need for greater diversity in the engineering field. Employers are looking for people with system-level skills. In addition to fundamentals, they need to think beyond technical details. With all the information available online, it is creativity that adds the value of engineers of today and the future. The future is about making the world better, people to live longer, the produce a better environment, not just making money.

The CDIO Initiative already from beginning has stressed the system-levels skills from many of its standards (Standard 1 – The Context, Standard 5 – Design Implement experiences, Standard 6 – Engineering Workspaces, Standard 7 – Interactive learning, Standard 8 – Active learning). We could argue that the CDIO standards drive towards the futures skills that Ehlers and Kellerman (2019) in their Survey report find central. We could argue that COVID-19 hinders from implementing the central CDIO standards, if not virtualization is carefully done.

Digitalization of education can provide the tools for going towards the goal of personal curriculums, more interaction with teachers, putting focus on problem solving skills, and fostering creativity. Correctly made digitalization has to possibility too free up resources to other tasks than basic teaching and exercise correction, freeing the teacher resources for the need of future skills.

RESEARCH METHODOLOGY

During November 2020, a half quantitative and half qualitative online survey with 68 questions with topic of “Digitalization in IT-department” was conducted in IT department of Åbo Akademi University. All 15 active lecturers from the department were involved. In total of 37 of 5 ECTS per course were analyzed covering subjects of information technology, programming, automation, internet of things, digital communication, engineering mathematics, algorithms, cloud computing, software and hardware development, data science and machine learning. Lecturers were asked to choose the most appropriate claims and/or describe freely in written about their courses from the beginning of COVID-19 until the end of November 2020 about the following topics:

- Teaching methods,
- Type of coursework,
- Grading methods,
- Course communication and interaction methods,
- Perception towards popularity and enrollment on their course,
- Challenges related to teaching and lecturing -technologies,
- Perceptions towards alternative teaching and grading methods

The selection of topics and questions was based on daily interaction of cooperating with teachers in development and arrangement of online teaching which started already before the COVID-19. Thus, a lot of knowledge regarding teachers' experiences was acknowledged before the survey was conducted. Two teachers out of 15 were randomly chosen to be interviewed formally after their survey submissions to let them explain their answers more throughout. The rest of the teachers (13) were involved in informal interview-like one-on-one or group discussions that were documented by taking written notes during the discussions. Referring to the experiences, survey results and interview results a list of issues, ideas, visions, and best practices were summarized.

RESULTS FROM THE SURVEY

The main observation based on the results of the survey are described briefly in the text sections below.

- The most common challenge was the time used in grading. It is viewed as manual labor taking resources from teaching. A typical solution is to use teaching assistants (TAs) to help in grading.

- Classroom whiteboards are used in general regardless of subject, even during lectures that are only given online using video. There is a need to lecture streaming cameras that can show the whiteboards in good quality.

- Some courses are using physical devices, like Arduino boards and Raspberry Pi's. These physical devices are an essential part of education and are hard to make working in a virtual version of the course. Changing from physical devices to virtual ones is possible up to a certain point where it would change the purpose and goal of the course too much. Related to the CDIO Initiative, the standard 5 Design-Implement Experiences clearly suffer.

- The use of group communication tools in teaching such as Slack and Teams are unfamiliar within the department. However, there is a latent interest and therefore a need for demonstrations of the tools of virtual communication. According to the survey, the general interaction during online classes has remained low. Instead of classroom communication, several students tend to send similar questions for teachers via email and therefore a common discussion forum would enable answering everyone at once and perhaps even motivate students into interaction by answering others' questions.

- Teachers want to record lectures in lecture halls, the normal environment for teaching. Recording lectures beforehand in home, office or at designated studio is considered an extra effort that could change the teaching experience from interactive lectures to passive education films.

- Most students work using their own laptops, so classes equipped with computers are not really needed any longer. This concerns mostly the programming courses. Moving from computer classrooms to BYOD (bring your own device) type of concept would bring more flexibility when choosing the environment for teaching.

Many still regard exams as an important part of learning. This on the other hand shows that students are still not motivated enough to learn but also that it is very difficult to measure and reward learning without testing. Exams are considered at the same time easy to arrange but resource consuming, resources here meaning the time of teachers and teaching assistants.

In spring 2020 before COVID-19, there were still paper exams and e-exams on campus. Most eminent changes have happened from the change of paper exams to other forms, for example, adding an extra assignment became a popular solution. Before COVID-19, the course projects were not graded as often. Writing exams at home and supervised via Zoom[8] became one of the popular COVID-19 solutions as well. In Figure 1 is represented grading methods per course. In 2019-2020, four more courses were arranged than in 2020-2021, which was not related to COVID-19. Using several grading methods in one course increased. Before COVID-19, 41 courses included 51 grading methods and during COVID-19 37 courses used 63 grading methods.

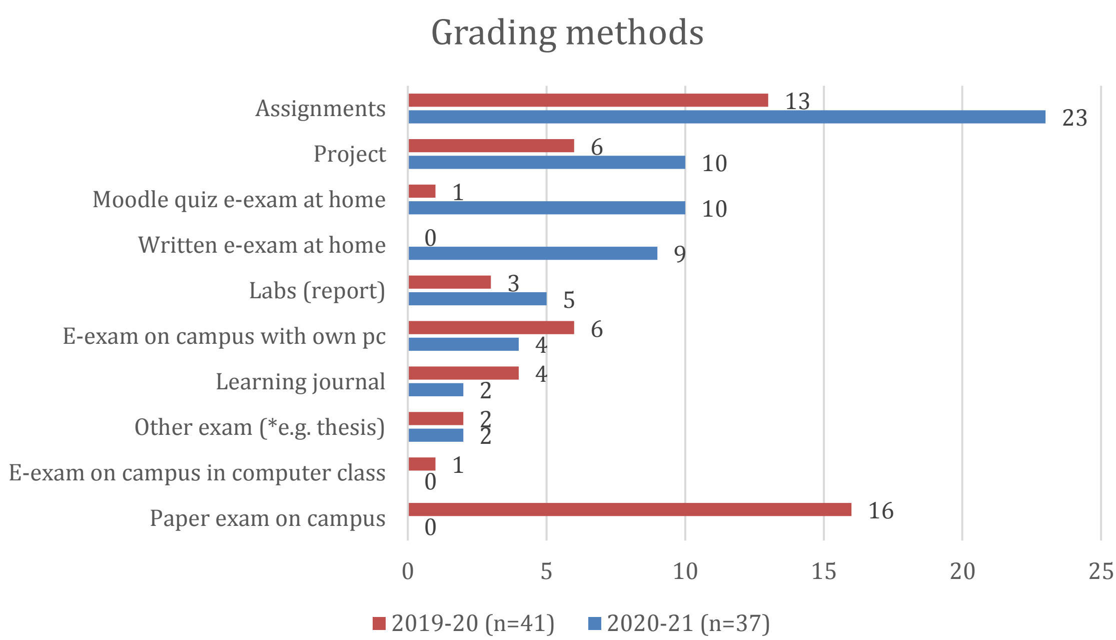

Figure 1. Grading methods used in courses. (2019-2020 n=41, 2020-2021 n=37)

COVID-19 did not change notably the types of coursework. In 2019-2020 semester two courses, with mandatory access to campus lab equipment, were arranged in periods two and three, just before the campus was closed. Same courses will be arranged again in spring 2021, by inviting students in small groups to campus, if possible. Below is a list of coursework used in 2020-2021. Only COVID-19 related changes were slightly increased utilization of quizzes and group work-related meetings done online.

- Written assignments: 19/37 (53%)
- Programming tasks: 19/37 (53%)
- Quizzes: 9/37 (25%)
- Other: 6/37 (16%)
    - Mathematical Moodle assignments, discussion seminars, group discussions etc.
- Group work report: 5/37 (14%)
- Learning Journal: 3/37 (8%)

[8] Zoom meetings and chat. Website: zoom.us

- Group work presentation: 3/37 (8%)
- Group work, other: 3/37 (8%)
  - Pair programming, group work sessions

A response to the open question "what should remain as non-digitalized? / "what should have not been digitalized" 18 out of 37 replies mention campus lectures or seminar sessions with classroom interaction and communication. Arranging final exams similarly to before COVID-19 was mentioned twice and the ability to arrange projects as before COVID-19 once. In 13 out of 37 courses, respondents did not specify any opinions for non-digitalization. Three respondents did not reply to the question.

In the follow-up question teachers replied that 54 percent (20/37) of courses could not be digitalized more by anyone. 46% (17/37) of courses could be digitalized by someone of which 30 per cent by the teacher and 16 percent by an education development professional or another skilled education professional.

WHAT IS SIMILAR, WHAT IS DIFFERENT?

Going into COVID-19 mode in March 2020 was for many a very abrupt change in working habits. In one week, you should prepare to start giving courses in a format where physical distancing is the norm. The preparation of this included finding if you have suitable equipment, i.e., video cameras, microphones, workspace, computer screens, network connectivity. Most of this had been worked out already at the department if IT, as we had been doing digitalization of education already earlier. However, we could then use equipment available on the campus. Now, we were dependent on personal equipment available at home.

At Åbo Akademi University, an internal teacher and student survey (Wikström, 2020) was performed after spring 2020. That survey showed that the students at the faculty of natural sciences and technology were the ones that were happiest with the distance education given. Both teachers and students had the best knowledge of the technical tools required for remote education. However, in that study, there was already a clear indication of lack of motivation for studies.

To some extent, courses could continue just as before, the major difference was that everything was streamed over Zoom. So, the *what*, and *how* continued as before, the *where* was changed. However, quite soon the *how* also changed. The normal student interaction was missing, the normal after class-discussions with students disappeared, and the discussions with other teachers was not there. Moreover, latest when moving into exams, there was a change of how the exams were performed. The traditional style of doing exams in lecture rooms using pen and paper has now changed to different on-line formats, with fears of being unfairly treated.

In a report by Di Pietro et.al. (2020), the authors list four different elements that are assumed to cause learning loss due to COVID-19 and remote education: 1) Less time spent in learning, 2) Stress, 3) A change in the way students interact 4) Lack of learning motivation. Based on the surveys performed, at least 3) student interaction and 4) lack of motivation was clearly visible in the results.

Realizing that COVID-19 was not just a temporary break in normal habits, but a significant change in how we should work, as the extension of remote studies was prolonged first until the end of fall 2020, and then for the spring semester 2021, there was a change in mindsets of the teachers. Now, we really needed to consider *how* to do the courses. This *how* varied per course. Some courses needed really rethinking, whereas other courses could rely on the digitalization efforts already done.

QUALITY OF EDUCATION

The change in quality of education has been rather hard to evaluate so far. The quality of education is dependent on several factors. It is the course curriculum, the teaching material, the teaching facilities, the lecturer, the assignments, the assessment, and the interaction. Quality can be observed by student performance and student feedback. Evaluation of teaching quality in the transformation to online teaching under COVID-19 would benefit from statistical comparison to e.g., grades given in previous years in the same courses. The comparison could, however, be affected by potential changes in course content, examination method, students' skills, and other events happening at the same time as that course, that should be taken into consideration.

COURSE DYNAMICS AND COMMUNICATION

The biggest change has been in the course dynamics. With dynamics, we mean everything that happens around a course. In the normal setup of a course, where students are present at physical lectures, the everyday small concerns are efficiently handled in discussions during the course. For the lecturer, it is very easy to follow up on how the teaching is perceived during physical lectures. You can see when you need to put more time into something, when a student does not follow the lecture for some reason or solve un-clarities in for instance exercises. In the COVID-19 restricted education, behind computer screens, this natural communication way of direct interactions was not there. Also, normally, the motivation for studies, the inspiration comes from the interactions during the classes, during the common work and group work. That was now missing.

The teachers could give free-text comments communication in the survey. In this survey, 8 out of 14 answers mentioned problems with communication. In the answers, we find "Students not replying to messages or emails", "No communication at all", "Mainly low interaction". In some courses, it seems to be working better, questions from students were mainly related to assignments.

POST COVID-19 DEVELOPMENT

Based on the survey we also analyzed what changes should be retained and which changes need to be discarded in the post- COVID-19 development of education. The things that need to be achieved are the following:

- More interaction between students and teachers
- Direct feedback on material and activities
- Class-room dynamics back into an inspiring format

On the other hand, COVID-19 has also forced us to take tools into use and make organizational changes that need to be retained:

- Microsoft Teams as a tool for course discussions and chats

- Virtual communities are now managed by the university (using tools like MS Teams, instead of having ad-hoc virtual communities)
- More on-line material gives new possibilities for off-site learning, which also supports the goal of life-long learning and learning autonomy
- Videos of lecturers can be very useful for students. Many students, for instance, watch lecture videos at 2x speed. Things that require more attention can then be repeated at normal speed. This makes it possible to adapt to the learning speed.

CONCLUSIONS

The department of IT at Åbo Akademi University had been doing systematic digitalization of education for more than a year before COVID-19 changed how education was being done globally. The question was – how well did the earlier digitalization process support go into almost 100% on-line education? Could we just go on as business-as-usual, just by talking over Zoom instead of in the same physical space?

During fall 2020, the teachers answered a survey to get information on how the teaching was going. As the first conclusion, based on the feedback from teachers over the survey performed, especially the automated correction of exercises was very useful. However, we believe that they are as useful in a real-world scenario as in an on-online scenario. The original idea was anyhow to let free resources to teacher work regarded as more important for quality – being present for discussions with students and develop the ways students think.

We realized was, that digitalization efforts that worked before the COVID-19 , also worked during COVID-19. The only difference is that the actual fruits of digitalization, to enable more interaction, innovation, and problem solving, were not realized due to COVID-19.

What on the other hand is very different is the teaching dynamics and the discussion spaces. Over Zoom the overall feedback is that discussions are hard to get going. You do not know how the learning process goes forward. In some courses, communication with students disappeared almost completely.

In the long-time perspective, we do not yet know how the actual learning has changed during the COVID-19, it is too early to say, as conclusive data is not yet available. It will be a study object for a long time, and we are sure that we can use this information for further developing the learning environment.

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BASIC NEED FRUSTRATION IN MOTIVATIONAL REDESIGN OF ENGINEERING COURSES

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ABSTRACT

Engineering Education aims at realizing students' satisfaction and intrinsic motivation. However, students' frustration is never fully banned. In this article, I argue that one of the reasons for the limited focus on frustration in Engineering Education is the limited focus on frustration in classical motivational theory itself. I focus on Self-Determination Theory and distinguish between the early work focussing on satisfaction and the recent work considering frustration as a distinct active threat. I will complement this theoretical approach with an empirical analysis of data from a large ethics of technology course in 2016 and 2020 at Eindhoven University of Technology. Two research questions are asked: "(RQ1) Do basic needs satisfactions and frustrations in the USE basic course confirm the asymmetrical pattern described in recent literature?"; and "(RQ2) Do basic needs frustrations add to the variance of motivation types?" I performed principal axis factoring with an oblique rotation to answer RQ1 and stepwise regression analyses to answer RQ2. I conclude that basic need frustration can be measured as a clearly different concept compared to satisfaction and that splitting these two concepts is helpful for Engineering Education when studying motivation. I discuss two main avenues for Engineering Education: motivational theories should take need profiles and need trajectories into account in course design; and motivational research should inquire how individuals can learn to cope adaptively with need-frustrating experiences.

KEYWORDS

Self-Determination Theory, frustration, basic need, motivation, engineering ethics, Standards: 3, 4, 7.

INTRODUCTION

Engineering Education aims at realizing students' satisfaction and intrinsic motivation to increase students' engagement and deeper learning (Bombaerts et al., 2019; Doulougeri & Bombaerts, 2019). However, students' frustration is never fully banned; often leading to frustration of course designers and teachers. In this article, I argue that one of the reasons for the limited focus on frustration in Engineering Education is the limited focus on frustration in classical motivational theory itself.

I take Self-Determination Theory (SDT) (Ryan & Deci, 2000) as example as it is currently a prominent motivational theory in Engineering Education (Bombaerts & Spahn, 2021). SDT provides concrete pedagogical advice by increasing students' three psychological basic need, “psychological nutrients that are essential for individuals’ adjustment, integrity, and growth” (Ryan, 1995; Vansteenkiste et al., 2020). Providing meaningful choices - not “whatever students want to choose” – increases students’ *autonomy*. A warm connection with peers and teachers will create *relatedness*. And a task that is challenging enough but not too difficult will increase students’ feeling of *competence*. SDT states that these basic needs influence different types of motivation. They increase *autonomous motivation* (motivation that is intrinsic or sufficiently internalised) and *controlled motivation* (motivation because of internal or external pressures) and decrease *amotivation* (no motivation, avoiding the task and caring about not doing it).

The early focus of basic psychological needs theory (BPNT) was on the satisfaction of the three basic psychological needs (Ryan, 1995). Research from Bartholomew et al. (2011) and Vansteenkiste and Ryan (2013) shed light to what they call the “dark side of human functioning” and basic needs frustrations. They showed that both satisfaction and frustration of basic psychological needs have an asymmetrical relation, as the absence of the one does not automatically mean the presence of the other. As such, they are both active threats and distinct concepts (Vansteenkiste et al., 2020). This empirically means that they appear as different factors and are negatively correlated. Basic need frustration also adds to the prediction of more negative aspects as ill-being. It indicates frustration entails extra functional costs like disengagement, distress (Bartholomew et al., 2011; Jang et al., 2016) and amotivation (Haerens et al., 2015).

In this article, I sketch some elements of this theoretical debate and link it to Engineering Education. I will complement this with an empirical analysis of data from a large ethics of technology course in 2016 and 2020 at Eindhoven University of Technology. I conclude that basic need frustration can be measured as a clearly different concept compared to satisfaction and that splitting these two concepts is helpful for Engineering Education when studying motivation.

CONTEXT

I briefly sketch here the course in which data are collected. I stress that this article has not the ambition to conclude course redesign recommendations based on the theoretical and empirical research. It is merely used as a contextualisation of how students’ need frustration can be measured in Engineering Education.

The context of this study is a basic course of ethics and history of technology. This basic course is a complex course, part of a set of four non-technical courses (Bekkers & Bombaerts, 2017) in the Bachelor’s study program focusing on “User, Society and Enterprise (USE)” aspect of technology. This ‘USE basic course’ is an eleven-week required course and takes place in the fourth quartile of the first year. In 2016 it consisted of a group of 1864 students at the start, from 15 different engineering training programs, offered in two languages (native Dutch and English) by two groups of teachers (the history and the ethics group). The students were divided in 8 groups of about 250 students for lectures on two different days of each course week, and in 32 groups of about 60 students for weekly tutorials. Students had one assignment in which they applied theories to an existing socio-technical problem. History and Ethics lectures were alternated to give input in a combined group assignment on Ethics and History of technology. The assignment weighed for 40% of the final grade, the theoretical final exam for an additional 50%. Finally, students could practice for the final exam with the help of 3 online quizzes. The two best quizzes counted for the remaining 10% of the final grade. The 2020 had several changes, but the overall large-scale complexity remained.

RESEARCH QUESTIONS

Based on the recent literature and this case, I come to the two following search questions: "(RQ1) Do basic needs satisfactions and frustrations in the USE basic course confirm the assymetrical pattern described in recent literature?"; and "(RQ2) Do basic needs frustrations add to the variance of motivation types?"

ANALYSIS

Procedure, Sample and Instruments

Students received an invitation by email to fill out an electronic questionnaire, asking for informed consent and no compensation was given. Researchers only could work with the anonymized master file, in agreement with the national law and the data protection officer.
The response rate was sufficient (Nulty, 2008) with 37.4% (631 out of 1702 students that handed in their end exam in the first exam period) in 2016 and 26.5% (439 out of 1654 students) in 2020.

Student *autonomous motivation* and *amotivation* was measured in 2016 and 2020 and *controlled motivation* was only measured in 2016, using the 'Self-regulation questionnaire–Academics' (SRQ-A) (SDT, 2014; Vansteenkiste et al., 2005). To measure basic needs in 2016, the *Basic Psychological Need Satisfaction Scale – Work Domain* (see BPNW "Basic Psychological Needs at Work," n.d. for items) was used measuring the three basic need satisfaction factors with 3 positively and 3 negatively formulated items. Reference to the USE basic course was added to the items. In 2020 the Basic Psychological Need Satisfaction and Frustration Scale (see BPNSFS; Chen et al., 2015, 227 for items) was used. It measures three basic needs satisfaction factors and three basic need frustration factors with four items per factor.

Factor Analysis

The motivational items in 2016 have been analyzed with principal axis factoring with an oblique rotation based on eigenvalues. Most items loaded on factors as expected with two main exceptions. One item of the *extrinsic* factor ("*I am motivated to study for the USE basic course because I'm supposed to do so.*") consistently did not load on any factor, therefore, this item was removed from further analyses. All items from *autonomous motivation* and *amotivation* loaded on their factor. The items from controlled motivation loaded on two factors, known in SDT as *introjected* and *extrinsic* regulation. The four-factor analysis accounted for between 69% of the variance. For 2020, two factors *autonomous motivation* and *amotivation* also appeared in a principal axis factoring with an oblique rotation with 65% variance explained. Cronbach Alpha reliabilities all ranged between .75 and .92.

To answer the first research question RQ1, also for the basic needs items, principal axis factoring with an oblique rotation has been performed based on eigenvalues and set the expected number of factors based on theory on two factors (in which I expect to find a division between satisfaction and frustration items) and six factors (where I expect to find the three satisfaction and three frustration items). I use notations as “Aut+” as the factor containing the positively formulated items of autonomy satisfaction and “Rel-“ the negatively formulated items of relatedness satisfaction. For the 2016 data, our analysis based on eigenvalues showed (See Table 1 loadings) 4 factors explaining 45.3% of the variance, roughly Aut+/Comp+, Rel+/Rel-, Aut- en Com-. Here “Aut+” refers to the factor of autonomy satisfaction and “Rel-“ to relatedness frustration. The two-factor analysis very clearly shows the split of positively and negatively formulated items with 40.0% explained variance. All 18 items loaded less between -.155 and 0 on the other factor, except for *Rel2-* “There are not many fellow students or tutors in my course that I was close to.”, which loaded for -.249 on the other factor. The six factor gives Aut+/Rel+, Comp+, Aut-, Rel-, Comp- and 1 rest-factor collecting 2 competence items with 49.8% variance explained.

Table 1. 2016 data pattern matrix, principal axis factoring with an oblique rotation based on eigenvalues and two and six factors, factor loading < .4 not presented. Aut+ and aut- refer to the BPNW scales with the positively and negatively formulated autonomy satisfaction items; same for Rel+, Rel-, Comp+ and Comp-.

	Eigenvalues				**2 factors**		**6 factors**					
Factor→ ↓Items	1	2	3	4	1	2	1	2	3	4	5	6
Aut+1			.595		.622		.469					
Aut+2		-.418	.461		.690		.728					
Aut+3					.624		.751					
Rel+1			.414	-.653	.704		.588			-.418		
Rel+2				-.630	.716		.705					
Rel+3	.510				.697		.717					
Comp+1			.588		.509							.829
Comp+2			.831		.565				.837			
Comp+3			.824		.569				.828			
Aut-1	.648					.593		.798				
Aut-2	.678					.526		.834				
Aut-3	.439	.483				.671		.524				
Rel-1				.620		.539				.676		
Rel-2				.770		.479				.769		
Rel-3		.543		.450		.623					.411	
Com-1		.776				.654					.856	
Com-2	.451					.612			-.460			.405
Com-3		.822				.698					.800	

For the 2020 data, the eigenvalues factor analysis showed (see Table 2) four factors explaining 49.8% of the variance, roughly Aut+/Aut-, Aut- en Comp+/Comp-, Rel+ and Rel-. The two-factor analysis again, although in a less clear way, shows the split of satisfaction and frustration items with 35.9% explained variance. The six factor gives Aut+, Rel+, Comp+/Comp-, Aut-, Rel- and one rest factor and explains 53.9% of the variance. Cronbach alpha’s for all these factors were between .70 and .85 (after deletion of 1 factor in Rel- “I feel the relationships I have in this course are just superficial.”).

Table 2. 2020 data pattern matrix, principal axis factoring with oblique rotation based on eigenvalues and two and six factors, factor loading < .4 not presented. Aut+ and aut- refer to the autonomy satisfaction and frustration in BPNSFS; same for Rel+, Rel-, Comp+ and Comp-.

	Eigenvalues				*2 factors*		*6 factors*					
Factor→ ↓Items	1	2	3	4	1	2	1	2	3	4	5	6
Aut+1		.492				.498						.406
Aut+2		.438				.619		.789				
Aut+3		.420				.680		.743				
Aut+4		.611				.629						
Rel+1				-.666		.557				-.606		
Rel+2				-.690		.559				-.682		
Rel+3				-.872		.599				-.863		
Rel+4				-.644		.535				-.618		
Comp+1	-.779				-.581		-.797					
Comp+2	-.798				-.641		-.748					
Comp+3	-.737				-.518		-.754					
Comp+4	-.708				-.506		.565					
Aut-1		-.761				-.420			.773			
Aut-2		-.714							.706			
Aut-3			.428		.422							
Aut-4		-.771				-.446			.794			
Rel-1			.485		.458						.598	
Rel-2			.589		.502						.586	
Rel-3			.602		.602						.677	
Rel-4							-.766					
Comp-1	.601				.793		.402					
Comp-2	.419				.683						.581	
Comp-3	.434		.555		.810		.479					
Comp-4	.514		.406		.772							.406

Table 3 provides correlations for the basic need scales for 2016 and 2020, respectively above and below the diagonal.

Model prediction

To answer the second research question RQ2, multiple stepwise regression analyses were performed, with basic needs variables as predictors, and motivation as dependent variable, to find out whether the inclusion of the basic needs frustration variables would increase the explained variance of motivation. In the first step of the analyses, only basic needs satisfaction variables were entered (Model 1 in Table 4), and in the second step, the basic need frustration variables were added (Model 2). Difference in explained variance (R^2) was calculated. The results of these analyses are shown in Table 4.

Table 3. Basic needs scale correlations. For 2016 (above diagonal), aut+ and aut- refer to the BPNW scales with the positively and negatively formulated satisfaction items; for 2020 (below diagonal), aut+ and aut- refers to satisfaction and frustration in BPNSFS.

Factor	*1.*	*2.*	*3.*	*4.*	*5.*	*6.*
1. Aut+	-	.58**	.45**	-.07	-.16**	-.21**
2. Rel+	.42**	-	.35**	.01	-.41**	-.17**
3. Comp+	.33**	.22**	-	-.10*	.01	-.08*
4. Aut-	-.50**	-.21**	-.24**	-	.31**	.40**
5. Rel-	-.03	-.19**	-.29**	.35**	-	.44**
6. Comp-	-.07	-.052	-.63**	.35**	.58**	-

Table 4: Summarized Results for Stepwise Regression Analysis for Predicting Motivation Variables with Basic Needs Variables. Model 1 = Aut+, Rel+, Comp+. Model 2 = Aut+, Rel+, Comp+, Aut-, Rel-, Comp-.

		Model 1		**Model 2**		
Dependent	**Year**	**R^2**	**F**	**R^2**	**F**	**ΔR^2**
Autonomous	2016	.39	115.12*	.39	186.7*	.00
Introjected		.13	29.89*	.18	23.49*	.06
Extrinsic		.06	13.93*	.22	29.30*	.16*
Amotivation		.11	25.13*	.28	40.21*	.17*
Autonomous	2020	.52	470 .3*	.56	181.6*	.04
Amotivation		.20	55.9*	.35	76.1*	.15*

*Note: * $p < 0.001$*

The results show that the addition of basic needs frustration variables gave a significant increase in predictive power for *extrinsic regulation* and *amotivation*. The inclusion of these variables seems important, as the explained variances show a strong increase from Model 1 to Model 2.

DISCUSSION AND CONCLUSION

In order to give meaning to the two clearly separated factors in the two factor analysis in the BPNW in 2016, we elsewhere propose to interpret them as ‘satisfaction’ and ‘frustration’ (Bombaerts & Spahn, 2021), of course knowing that this instrument is not validated to measure basic need satisfaction and frustration. Nevertheless, items as “I felt pressured to do things in a certain way during the course.” (*Aut1-*) show a clear frustration aspect. Doing this, both the 2016 and 2020 clearly differentiated factors. As such, I can confirm the first research question that basic needs satisfactions and frustrations in the USE basic course confirm the asymmetrical pattern described in recent literature. I should note, however, that the BPNW that is not designed to measure frustration gives a more pronounced separation than the BPNSFS that is specifically designed to measure it. Secondly, the analysis also confirmed that basic needs frustrations add to the variance of more negatively oriented motivation types as *extrinsic regulation* and *amotivation*. This means that for researchers who are interested in *controlled motivation* (*introjected* and *extrinsic regulation*), or *amotivation*, the basic need frustration variables should be included in their analyses, as separate variables.

I am aware this article has many limitations. First of all, the article is very exploratory. I do not use qualitative data to further understand *how* USE basic students experience their frustration, how students differ or show similarities, or how frustration changes. Furthermore, this article only uses two instruments of one motivation theory. As such, the article does not make a statement on motivation and frustration in general. A third limitation is the elaboration of existing literature of compensatory behaviour outside SDT. The only excuse I can bring in for these limitations is the paper length limitation, since they are all very important and need to be further elaborated.

The current literature studies how students confronted with basic needs frustration try to actively compensate for frustrated needs, such as developing rigid behaviour patterns, developing contingent self-worth, oppositional defiance, the pursuit of need substitutes or need sacrificing (Vansteenkiste et al., 2020). This is what teachers experienced in the ethics and history of technology course. Students asked to do an ethical analysis of existing socio-technical problem might experience difficulties with the openness of the assignment (Bombaerts et al., 2018; Bombaerts & Martin, 2019). They may compulsively hold on to specific routines that operate as scripts for the behaviour they imagine they need to do. Some students for example stick to technical engineering methods to solve a problem instead of using more social science methods in the hope they find temporal forseeableness, security or stability (Deci & Ryan, 2000). Students can develop contingent self-worth (Kernis, 2003). Resistance to engage in a non-technical course and in-group expressions of “use is useless” can be interpreted as signs of active compensation attempts to find a balance between the current, often more technical, view on engineering and the alternative views proposed in an ethics of technology course. This can lead even to oppositional defiance if this when students more publicly raise these concerns and try to use tutorials to find group support to escape from an experience of control (Koestner & Losier, 1996). A far less extreme and almost general reaction to basic need frustration is the shift from an intention for deep learning to surface learning (Koestner & Losier, 1996). as a pursuit of need substitutes and need sacrificing (Holding et al., 2020).

Vansteenkiste et al. (2020) give several future directions for basic psychological need theory. Two avenues are of particular importance for this study. Firstly, as Vansteenkiste and Mouratidis (2016) illustrate, SDT should take need profiles and need trajectories into account. Course redesign will increase with better insights in clusters of students sharing a same basic psychological need, both satisfaction and frustration, when confronted with specific requirements from an engineering education course (Warburton et al., 2020). Gillet et al. (2019) showed considerable heterogeneity in need trajectories, illustrating the importance to be well aware how students might experience frustration during the course. A second avenue relevant for this study is that motivational research should inquire how individuals can learn to cope adaptively with need-frustrating experiences. Frustration in itself is not a bad thing. It can be a positive sign of a technical worldview being confronted with more complex socio-technical challenges. Waterschoot et al. (2020) for example showed the role of feedback to coping strategies using competence-relevant cues. Good feedback in Engineering Education (Bombaerts & Nickel, 2017; van Diggelen et al., 2019) can also shift students frustration and resilience to motivation and engagement.

This opens a broad range of further questions for research and education beyond the scope of this article. Is there a difference between good, constructive and bad, destructive frustration? Should education steer toward constructive frustration for better learning or should it avoid this and only aim for satisfaction and intrinsic motivation? How to recognise and constructively use good frustration in engineering education?

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FLEXIBLE TACTICS TO FACE COVID-19 AND SOCIAL OUTBREAK IN CHILE

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ABSTRACT

The COVID-19 pandemic can be considered as one of the world's largest crises in the last century. Its effects are observed in many fields, and tertiary education is no exception. In Chile, its impact has been exacerbated by an ongoing social outbreak since October 2019. This context motivated huge changes in the way engineering courses are taught and how learning is achieved and assessed. The situation is causing difficulties to students and teachers, who still manage to overcome them and advance in the teaching-learning processes. This article describes a set of flexible tactics implemented to manage the general context existent during the first term of 2020 at the School of Engineering and Science of Universidad de Chile. We provide testimony of the situation we faced and guidance for similar courses. The case study corresponds to a compulsory course in the Mechanical- Engineering curriculum. Restricted evidence (self-perception surveys of 24 students) supports effective delivery through increased flexibility in the use of teaching-learning and assessment tools and frequent monitoring of student's attitudes and perceptions. Evidence supports the achievement of the course learning goals. Lessons learned helped designing a new version, still in online mode.

KEYWORDS

COVID-19, Chilean social outbreak 2019, emergency remote teaching, online learning, active learning, Standards: 6, 8, 11

INTRODUCTION

It has been written many times that ours is a period of volatility, uncertainty, complexity, and ambiguity. Without a doubt, 2020 was hard proof of it. The COVID-19 pandemic has been a shock for mankind. Social and economic systems have been battered seriously, and recovery is expected to last several years. Education, as a whole, is no exception. The forced move in tertiary education from face-to-face to online learning is still in its infancy and is certainly a challenge that is leading to a new equilibrium, where traditional methods are being adapted or replaced. The situation presents itself as a crossroads for education, as face-to-face is moving to blended and full online in the long term, on a massive scale. Chile is also experiencing a social outbreak since 2019 (SO-19) that questions the viability of the free-market economic model in place for the last 40 years. COVID-19 and SO-19 are major drivers for growth in delivering enhanced engineering education for the XXI century.

At the beginning of the first term of 2020, Chile was returning from the summer holidays and had few cases of COVID-19. Expectations regarding SO-19, which started in October 2019, were very much present, especially in a public institution like Universidad de Chile. By the third week of March, the University suspended face-to-face teaching. The academic community had almost no experience regarding Online Learning (OL). In a survey during June 2020, 78% of the teachers (N=228) declared no previous experience in OL (Bravo & Solis, 2020). Teaching at the School of Engineering and Science of the Universidad de Chile was mainly traditional, most courses were based on face-to-face interactions. Many students did not possess broadband internet nor personal computers and/or adequate space for exclusive use at home. SO-19 meant, already for the second term of 2019, a serious disruption to teaching and assessment methods. Most teachers opted to replace traditional exams with homework, hoping for low cheating rates. Many average grades increased significantly compared to regular semesters. As a result, the capacity of the University to warrant the attainment of program-level learning goals required a revision.

The uncertainty given by the social and pandemic context of the country made it difficult to know beforehand how students would react. A part of the student community showed resistance to start a fully online semester. The climate was not the best, and two consecutive student strikes occurred in March and April 2020 to ensure fair conditions to carry on the term. Social, political, and sanitary issues mixed with the academic context, increasing problems related to students' workload and mental health. The picture was not clear at all, and with the inertia of the social outbreak, student representatives wanted to be heard by the School authorities. The need for dialogue and adjustments to unite and meet the needs of the students was becoming more and more evident.

The combination of COVID-19 and SO-19 forced courses' redesign on the fly. The state of affairs made it mandatory. Course redesign in the context of deep uncertainty requires a paradigm that is not based on ordinary conditions ("plan and deliver"), but that aims to prepare and adapt by monitoring how the context evolves and allowing adjustments over time as updated information becomes available. This "observe and adjust" paradigm recognizes the uncertainty surrounding teaching and assessment under changing scenarios. Yet, it is important to respect core educational values that require reflection.

This paper reports the experience faced during the first semester of 2020 in a fifth-year Mechanical Engineering course at the University of Chile. This shows the initial approach to develop the course and how it was adapted as the monitoring process took place. The results obtained from the evidence collected in each one of the interventions, the discussion that came out of that, and the lines of work projected for future semesters are also described.

RESEARCH QUESTIONS AND LITERATURE REVIEW

The forced move to ERT created a course (re)design need. The following research questions were stated for that purpose:

- RQ1: Which teaching-learning framework(s) is/are better adapted for OL?
- RQ2: How to help our students cope with the term in the context of general adversity?
- RQ3: How to assess learning properly in OL without overloading our students?

Before COVID-19/SO-19, the dominant form of teaching was based on traditional synchronous learning (SL). The sudden change from face-to-face to OL creates a non-physical (transactional) distance between learners and the teacher. Moore (2019) presents the classic theory of transactional distance (TD). Garrison (2017) proposed the Communities of Inquiry framework. We selected TD, which is well suited for instructional design for online education and provides a plausible answer to RQ1. TD theory poses that it is not the geographical distance between a teacher and student that impacts learning outcomes, but the cognitive distance. Moore postulates that Individual feedback, dialogue, and autonomy can narrow the distance. Reducing TD among students and the teacher, and interactions among students enhance the achievement of learning goals.

OL requires higher levels of self-regulated learning (RQ2), as the responsibility of learning is transferred to the student to a greater extent. Self-regulated learning emphasizes control and autonomy by the learner who monitors, directs, and controls actions toward goals of gaining expertise and self-improvement (Paris, 2001). Educators can teach self-regulated learning skills by using strategies such as Problem-Based Learning (PBL) (Hung, 2011), and Project-Oriented Learning (POL) (Beckett et al., 2019; Pascual & Anderson, 2014). Students' use of learning strategies is based on the belief that these strategies are necessary for learning, and are effective for overcoming obstacles (Dweck & Master, 2008). Yet, many of them show low levels of study skills, time management, and coping with stress (Maier et al., 2013). Havenga (2020) implemented PBL in an online class, finding out that a teacher's presence is essential in the process of learning, and working in groups allows active learning and commitment of the students. OL engagement is often achieved using active learning activities in small groups where one or more students act as *champions* (Maier et al., 2013). In such a mode, a student gets control of the class whiteboard and develops, in collaboration with her peers and the teacher, a proposed problem.

Excessive cognitive load (CL) was also a concern in our context (Karaka, 2017). CL is often distributed in traditional face-to-face learning among attending class, homework, and synchronic evaluations (RQ2). With the forced move to OL, a large portion of the load was transferred to homework (including evaluations with extended lead times). Such a situation implicates an increased CL for students, who faced many homework deadlines during the term. Excessive CL negatively affects the students' performance, learning, and levels of anxiety. One way to manage CL is using blended learning (BL). This consists of giving the students class materials to learn the theory beforehand and participate actively in class. BL allows students to learn at their own pace, increasing reflection, and decreasing anxiety. Karaca & Ocak (2017) explores BL and concludes that if well implemented, can reduce CL to the students. Another tactic to reduce anxiety is to gamify the class. Wang & Tahir (2020) provides a review of game-based learning as an effective tool to reduce anxiety.

Another aspect of interest is the stress-coping strategies of the students (RQ2). Visozo (2019) suggests that academic burnout could be prevented by the development of appropriate tactics and improving students' disposition, which positively affects students' performance. Bedewy & Gabriel (2015) identify four factors that affect students' ability to cope: academic self-perceptions, perceptions of workload, pressures to perform well, and time restraints. This list could be negatively affected by the effects of the pandemic context.

Different studies show that grit in college students is decreasing (Duckworth, 2016; Direito et al., 2021). The combination of COVID-19 and SO-19 would affect how students react to adverse conditions. Future engineers are expected to develop technical skills and the ability to adapt to uncertainty. Yet, initiatives designed to address the psychological demands of

engineering are uncommon (Pascual et al., 2021). This raises interest in understanding non-cognitive factors and how they are affected by uncertainty. In this line, (Direito et al., 2021) conducts a review on the subject and confirm that studies on this area are still very scarce.
Related to students' non-attendance to online classes (RQ2), Sloan et al. (2019) shows that the modality of the class has an impact on attendance; in order from highest to lowest probability of student attendance: laboratories, seminars, tutorials, and lectures. In OL, students often get the option to check the video a posteriori, instead of attending the live class. If they do so, they miss the opportunity to interact but gain the freedom to study at their own pace. Such *vicarious* learning mode could mean very poor attendance to the online class, affecting constructive discussions.

Among the student's coping strategies, cheating can increase (RQ3). Academic integrity is a global problem that needs to be faced, especially for OL. For example, a survey in the United Kingdom found that approximately 15% of students recognized cheating, and 40% knew someone who had plagiarised (Maier et al., 2013). The pandemic context has increased the risk of academic integrity issues during summative assessments.

Regarding assessment (RQ3), available video conferencing platforms do not provide supervision capabilities for assessments. Chao et al. (2012) study the impact of synchronous assessments in online environments focusing among other subjects on the extent of cheating and the need for a variety of methods for the different subject matter. In line with our approach to developing self-awareness, Esparragoza et al. (2014) develop a 30-item instrument to assess ethical awareness in Engineering students. Attempting to ensure proper individual learning in OL, Cramp et al. (2019) describe lessons learned from implementing remotely invigilated online exams (RIOEs). According to the authors, RIOEs require a more systematic and effective design compared to traditional paper-based exams. Successful implementation of RIOEs should be supplemented by early communication with students.

PROPOSED METHOD

High levels of uncertainty related to the combination of the social outbreak and global pandemic impulsed us to move from the traditional "plan and deliver" to "observe and adapt". The change to OL and increased student self-regulation support the use of PBL and POL.
The guiding principle for any adaptation during the term was "To ensure the learning goals while reducing non-core activities and keeping proven techniques to avoid increased student's anxiety and decrease transactional distance".
In this context, selected key tactics (KT) are:

1. Ensuring, with active learning approaches, the achievement of the core competencies described in the course program.
2. Using synchronous assessment to minimize excessive CL and academic integrity issues. For example, limiting the time to answer and using pools of questions.
3. Providing frequent occasions for monitoring climate, increasing dialogue, and reducing transactional distance, creating spaces to build rapport, and show empathy for the difficult times that many, if not all students, were going through. At the same time, provide schemes to reduce student's anxiety.

Below, we describe the tactics that were implemented to put the key tactics into practice.

CASE STUDY

Our case study considers a compulsory course placed during the fifth year of the mechanical engineering curriculum at Universidad de Chile. According to the program, at the end of the course “Operations management”, the student must be able to engineer proposals to improve operations in the context of public and private organizations. To do so, the student must be able to analyze operational problems using quantitative modeling tools. Before this course, students have been taught optimization, probability, and statistics courses. The baseline syllabus for the term included an exploration into skills for life and career (this strategy is described in detail in Pascual et al., (2021)). There were 24 students in this class.

KT1: Adapted active learning

We considered the following PBL approach: At each class, a champion leads his peers in developing spreadsheet-based cases with the teacher’s facilitation. The screen of the champion was shared on the teleconference platform. Class videos and source files were uploaded and made available to the students on the same day as the class. We also considered a group project (POL), with a duration of 15 weeks. Partial and final reports and presentations with flexible dates, following the uncertain agenda. The weight for each partial was different (25%, 35%, and 40% respectively). Each group selected its project from a pool of alternatives, providing an opportunity for personalized learning. To facilitate critical-thinking development, a global concept map of the course was collaboratively developed all along with the term. The map included class dates to map class videos to course concepts easily (IHMC, s. f.). To provide a final instance to share knowledge, an open webinar was offered.

KT2: Synchronous assessment

Three evaluations were made, with flexible dates. Each one took two hours, with two questions from a pool. Pools ranged between 9 and 21 questions. We considered that two hours were a reasonable limit to avoid fatigue. Questions were posed in sequential rounds, 1 per hour, with a 10-minute break in between. A third optative question was offered during the next week. If the student used this option, he/she selected which two questions had to be considered for grading. As for the project, the weight for each partial result was different.

KT3: Monitoring, reducing distance, and reducing anxiety

We developed several sequential surveys to monitor climate and adapt tactics, if necessary. We wanted to measure the different learning perceptions and experiences that students have in every instance of evaluation to come up with improvements. The first and second surveys had a total of 19 answers, and the third one had 18 answers. We used a 5-point Likert scale (from strongly disagree to strongly agree). The response rate ranged from 75% to 79%. In what follows we summarize the survey's results and how the teaching team reacted timely.

Data Source

After each partial exam, a survey was prepared to gain evidence to adjust the course if necessary. The questions aimed to explore various factors that were not clear at the beginning of the study. As mentioned before, the strategy adopted was to observe things that seemed important at the moment and could add value to improve the core characteristics of the course. The surveys evolved with every intervention, guiding to adapt and improve the course. Also, 7 students were interviewed at the end of the term.

Procedure

Participants completed the questionnaires using an online survey platform. The procedure to collect this data was to deliver the survey to students in a synchronous manner at the end of the class after each partial evaluation. The survey was anonymous.

RESULTS

First survey

The first survey was taken during week 6. Its focus was to know if students had proper access, resources, and fundamental tools to accomplish the exam. Students showed to have the necessary conditions to face it (table 1). 69% of the students said their internet connection did not impede them to complete the test. Also, 69% agreed they have the appropriate equipment to work. On the other hand, 15% did not agree. This raised an alert to explore particularly each case for future evaluations. The 25% said their physical space made the process more difficult compared to the traditional in-classroom tests.

Table 1. First survey. Student's perceptions.

Conditions during the term	Positive	Neutral	Negative
Internet connection	69%	16%	15%
Equipment (computer, tablet, etc.)	69%	21%	10%
Physical space	58%	17%	25%
Difficulty and alignment with course content	79%	16%	5%
Suitable time of answer	26%	32%	42%
Optative question	63%	26%	11%

A 79% of the students stated that problems on the test were aligned with what was seen in class (Table 1). This supports the hypothesis that in terms of content and difficulty, the evaluation was adequate and that there were external factors that made the experience different from a traditional evaluation. 26% of the students considered that the time assigned to answer each question, allowed them to solve and send/upload them to the platform without problems. 42% mentioned that the time was insufficient. 63% reacted positively to the opportunity to choose which two of the three questions would count for grading. This alternative reduced their anxiety and made them perform better. Also, several commented that keeping the camera on, augmented their anxiety. From this point, it was not mandatory to use a camera for the remaining assessments, the optative question was kept for its benefits, and the time to answer was increased from 60 to 70 minutes.

Second survey

The second survey was taken during week 11. 79% of the students agreed that this was their only course with a synchronous assessment. Most students had asynchronous assignments with long deadlines. In practice, this may translate to more time and work dedicated to each evaluation, and potential excess of CL. The main difficulties (Table 2) regarding the test were anxiety (88%) and poor internet connection (41%).

Table 2. Second survey. Main difficulties during the test.

Main difficulties during the test	Agree or Strongly agree
Stress and anxiety	88%
Poor internet connection	41%
Poor feedback from the teacher	23%
Poor skills in Excel	17%

After the first partial exam, attendance dropped considerably (Figure 3). It was necessary to understand the perceptions and behaviors, especially of the students who didn't attend. 58% answered that they attended less than 50% of the classes, and 42% of students to 50% or more of them. Only 9% of those who attended less than 50% said they felt satisfied with their learning.50% of those who attended 50% of the classes or more, showed they were satisfied with their learning outcomes (Figure 1). Synchronous attendance seems to play a positive role in the learning experience of the students in this course.

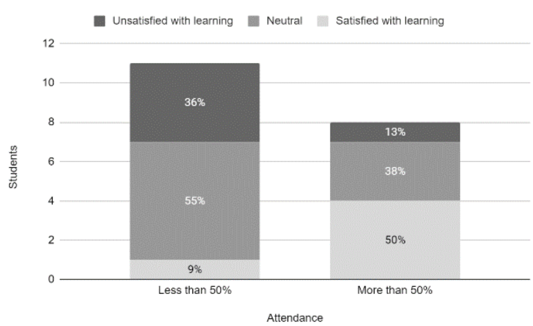

Figure 1. Second Survey. Attendance vs satisfaction with their learning outcomes.

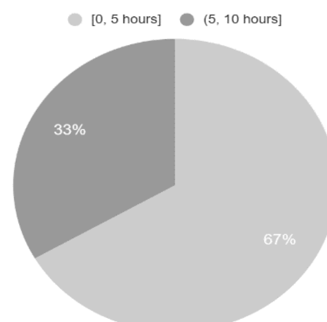

Figure 2. Second survey. Average weekly course dedication reported by 18 students

Students were asked to share their study strategies. 89% of students answered that their main source for studying was watching asynchronously the class videos, followed by solving the study guides (39%) and practicing in class (33%). 56% of the students watched the class videos weekly and 44% watched the videos a few days before the test. In terms of academic workload, for a course of 6 credits like this, it is expected that students may dedicate between 9 and 10 hours weekly to activities related to the course (classes, evaluations, self-study, etc.). In this case, just one student reported occupying the 10 hours required by the course program. 67% of the students reported spending 5 hours or less in activities related to the course. The evidence shows (Figure 2) that most of the class spent less than 50% of the time they were supposed to invest in the course. Such a strategy possibly affected their ability to answer the tests in the allotted time, increasing their anxiety.

Third survey

The third survey was taken during week 14. 15% of students stated that they felt more nervous and anxious in the third test than in a traditional face-to-face test. Some reasons declared by the students were related to test duration ("the test could last longer") and time management (they missed having the opportunity to distribute their test time alternately in the question they preferred); 55% agreed that the optional question helped them to reduce anxiety. 67% answered that their attendance to this course was similar or even higher than in other courses they took in the semester. Students recognized that the lack of attendance and participation in class was due to the pandemic context and the stress and workload (of all courses) during the final weeks. Most students preferred to study by watching the class videos. These acted as tutorials and showed them how to solve the problems.

Post-course assessment

Figure 3 shows the attendance of online classes during the term. Before the first partial exam (the orange vertical line), its levels are similar to those perceived as normal to higher for a face-to-face context. As can be seen, attendance fell to about 20% on average after that.

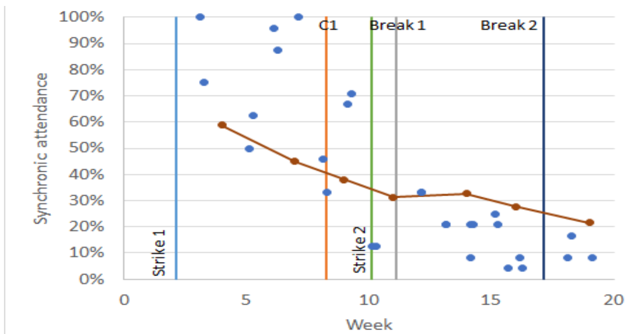

Figure 3. Synchronous attendance. Orange line refers to the first partial test and the brown line to a mean value of 113 courses during the spring 2018 term (Celis and Orellana, 2018).

To obtain more information about the students' perspective on the course and the remote modality, surveys were taken throughout the semester and, after the completion, 7 students were interviewed. This section presents the principal results obtained from their testimonies.

The students reported having an average of 6 courses and 29 assignments, in asynchronous mode, during the fall term. The semester is divided into 15 elective weeks, having an average of 2 home assignments per week. Despite the academic workload due to the assignments, 3 of the interviewees said that having more time for the evaluation was helpful for their learning, giving them more time to think and analyze the topics seen in class.

One of the concerns was how to know if some students were cheating. Students commented that they understood this practice was harmful to their learning. Cheating meant that they were not gaining the necessary knowledge that was part of their training as professionals. They commented that a common practice was to compare the results of problems with their classmates after doing them on their own. They mentioned this as one of the benefits of asynchronous evaluation because they had time to think and analyze each issue.

Also, some students preferred to watch the class videos out of the established schedule. Such a practice allowed them to adapt to the context of their homes. Many preferred to learn in a tutorial (vicarious) mode. This is one of the learnings from the adaptation process experienced during the year 2020. Today the internet allows access to a lot of information on different subjects, and a large part of the population can learn by watching others learn.

Some students said that the PBL methodology made them feel anxious because of the possibility of being champions and not having the skills to achieve it. However, in a survey done by the University at the end of the course, answered by 23 of the 24 students in the class, they valued the innovative teaching style positively. They saw great potential in the method and the results obtained, as it allowed them to put theory into practice immediately.

The school conducted a survey at the end of the term to evaluate courses and teacher's performance, which showed favorable results for this class. Students recognized the role of the teacher in their process of learning and gave some recommendations to improve methodology. For example, create a calendar with the assigned champion for each class to decrease students' anxiety. Also, 83% of 18 students who answered the survey, agreed that the professor promoted a fluid and permanent interaction in the virtual classroom (reducing transactional distance), made available support resources, and linked class contents with previous knowledge. 55% of students agreed that class methodologies motivated their participation, and they were oriented to perform the activities in an autonomous way.

The following are some of the comments made by students in the surveys:

"...In general, I was quite nervous before the mid-term assessment, but seeing that the questions were short and easy to understand, I knew that there was no need to worry too much." (first survey, May 2020)
"All classes are different and dynamic. The online modality is well adapted to the teacher's style of teaching, with a champion who solves a problem in excel and the teacher guiding her..." (third survey, July 2020)
"The problems of the exam are not particularly difficult, since the class itself is not difficult, it is the time given to solve the problems that increase stress…" (third survey, July 2020)
"The teacher was very respectful and very open to dialogue throughout the term, which is very much appreciated in these uncertain times." (end-of-term survey, August 2020)

Few persons had problems with the modality of the summative evaluations. One of the main reasons is they have to share spaces with family, making it difficult to be focused for a couple of hours. The majority of the interviewees could adapt to this modality, and it wasn't a general complaint. The last point was confirmed at the end of the course with the survey carried out by the University. Students declared that the teacher gave the conditions for all the students to participate in the evaluations. This finding offers the teachers, who are in the process of adapting, the space to try out new things and methodologies not yet tested.

DISCUSSION

Several reflections came to mind after the first term course of 2020:

1. We suspected deficiencies in self-regulated learning and time management in the students. Weekly dedication to the course is close to 50% of what is supposed to be. This could be one of the reasons that made students feel high levels of anxiety during the tests. These observations are consistent with those mentioned by Maier et al. (2013).
2. In the context of OL, In-class interaction is very difficult to assess by the teacher, as most students keep their cameras off. Low attendance existed during the second part of the term. Most students preferred to check the class afterward, at their own pace. This practice reduced dialogue and increased transactional distance, probably affecting learning outcomes. Many students tend to prioritize courses they consider more difficult or have the closest evaluation deadlines. Asynchronous resources play an important role in providing time freedom and serve the student to study afterward, as a video tutorial. Class videos could serve as flipped content for upcoming semesters.
3. The proposed synchronous evaluation system was accepted by most of the students. Dealing this exceptional term with a tactic of measuring and adjusting, allowed to reduce TD via dialogue between the teacher and students as the term progressed. Students felt

heard and understood that their feedback was useful to improve the course. Student's attitudes and the class climate evolved positively. All students approved the course.

4. Anxiety and lack of time to solve tests were present, just as in the face-to-face modality. Internet connection problems contributed to increased anxiety compared to traditional exams. Giving more time and offering the possibility to choose the questions students wanted to be graded was well received. The evaluation system served as a valid way to simulate an evaluation environment that was not far from a face-to-face mode. This assessment mode did demonstrate individual learning outcomes.

CLOSURE

This paper describes a practical set of tactics to manage the combined crises of COVID-19 and SO-19 at a senior course of mechanical engineering at Universidad de Chile during the first term of 2020. We summarize how the course was updated to handle the disruptive environment we had to face, exploiting a "monitor and adapt" approach during a volatile term. Results show that the updated version of the course was positively absorbed by a majority of the students. Synchronic exams, if well implemented, can be used to assess learning goals. COVID-19/SO-19 was an opportunity for students to gain skills for the XXI century job market. Self-regulated learning strategies need to be addressed with fresh regard. The move from the classroom to a context where learning may be facilitated in several ways pushes the frontiers of education. Also, after all this situation, working online is a possibility that will be common in the near future. This adaptation process prepares students for a professional future where online interactions will be frequent.

FUTURE WORK

From the results obtained through the reflection of the first term of 2020, the following actions come to mind for the second term and beyond:

1. Increase blended learning by creating a library of content. Use videos and source code files of the first term as tutorial content. Explore during class time to increase available learning material with deeper content and enriched discussions. We hope that using some of the available off-class time will not be an issue as they declared the low occupation of that time during the first term of 2020, and it will allow them to keep the pace of the class.
2. Incentivize online attendance with increased interactivity, game-based learning (i.e., Kahoot), and bonuses. Use small group activities to increase participation. Create a schedule to inform students who will be champion in each class.
3. Projects will be presented in an open online seminar that includes presentations from industry leaders and academics ((Pascual, 2010) explains the initiative).

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