Evaluation of students' performance in CDIO projects through blended learning

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EVALUATION OF STUDENTS' PERFORMANCE IN CDIO PROJECTS THROUGH BLENDED LEARNING

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ABSTRACT

Current engineering job sectors do not only demand theoretical technical knowledge but also hands-on skills and critical thinking to ensure that engineering graduates are adaptive to the evolving and innovative world. Hence, several engineering modules at Canterbury Christ Church University have incorporated CDIO projects to integrate professional skills into the course. Following the UK government COVID-19 lockdown guidelines in 2020, traditional on-campus face-to-face learning was restricted at UK universities and colleges; therefore, students faced several challenges from academic and wellbeing perspectives. To overcome the challenges and enhance those professional skills through CDIO projects whilst following COVID-19 restrictions, blended learning was implemented via reconfiguring the delivery and implementation of the CDIO projects through an optimal arrangement of online and on-campus sessions. Online CDIO practical sessions were dedicated to students for transforming their ideas into feasible designs and solutions whereas students developed the hardware prototype during the face-to-face sessions. The learning framework was inclusive with additional support for disabled students with accessible learning materials and supportive technical and professional training. The above strategy also helped students to complete their online assessment to achieve the required professional attributes and manage online/blended group-based tasks appropriately. Their outcome of the CDIO project was impressive and the quality of those projects is comparable to final-year projects. The performance of the students was also encouraging as the first-time overall pass rate is relatively high (86%) for a cohort of 75 students where average marks are around 59.6 and standard deviation is around 18.5. The high success rate was achieved in all areas of the cohort, for example the pass rate in BAME students was 93.75%, in female students it was 98.43%, and in disabled students it was 98.43%. A survey on students' experience shows that they benefited highly from the sessions related to the CDIO project.

KEYWORDS

Blended learning, CDIO project implementation, Inclusive learning, Professional skills, CDIO Standards 3.0

INTRODUCTION

The advancement of technology has changed the required skills of engineering job sectors where applicants should have up-to-date technical and professional skills and have the ability to adjust with the current trend (Pusca, Bowers, & Northwood, 2017). The present engineering trend supports Industry 4.0 (Diez-Olivan, Del Ser, Galar, & Sierra, 2019) which refers to the fourth industrial revolution in the manufacturing and industrial sector. It includes the application of advanced robotics, smart sensors, Internet of Things and advanced automation. Therefore, it is required to include more project-oriented skills in the curriculum as it enhances several competencies in students so that they would come up with innovative ideas through critical thinking, have the ability to solve problems, improve their competency in hands-on skills, engage in teamwork, and improve project writing skills, strategic competence and future vision. Recent qualitative research suggests (Llorens, Berbegal-Mirabent, & Llinàs-Audet, 2017) that aligning professional skills in active learning methods can establish a satisfactory engineering skillset. Critical thinking (Pee & Leong, 2005) is one of the essential skills that encourage students to choose the best alternative solutions for a specific problem. Other important professional skills for engineering students are teamwork and communication skills that would help them to resolve the conflict between individual contribution and provide the best solution (Ercan & Khan, 2017). Along with these skills, writing a project business report (Zainuddin, Pillai, Dumanig, & Phillip, 2019) is required for standard documentation in the industry. In the UK, for engineering students, hands-on skills are identified as one of the important learning outcomes in most of the modules and they must be developed within the higher education curricula by the UK engineering council and accreditation bodies (Engineering Council, 2014). Nevertheless, the lack of an innovative learning framework in engineering education especially in STEM areas leaves several employability skills unaddressed such as critical thinking, statistics, computing ability and so on (Siregar, Rachmadtullah, Pohan, & Zulela, 2019).

To overcome those problems, engineering modules are integrated with CDIO projects to embed better professional skills in the curriculum at Canterbury Christ Church University (CCCU) (Manna, Nortcliffe, & Sheikholeslami, 2020). Each of the CDIO Standards is intended to be fully integrated into engineering programmes by corresponding teaching and learning facilities at CCCU (CDIO, 2020), shown in Figure 1. CDIO (Chuchalin, 2020) framework builds an interactive platform for students where they 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 its improvement.

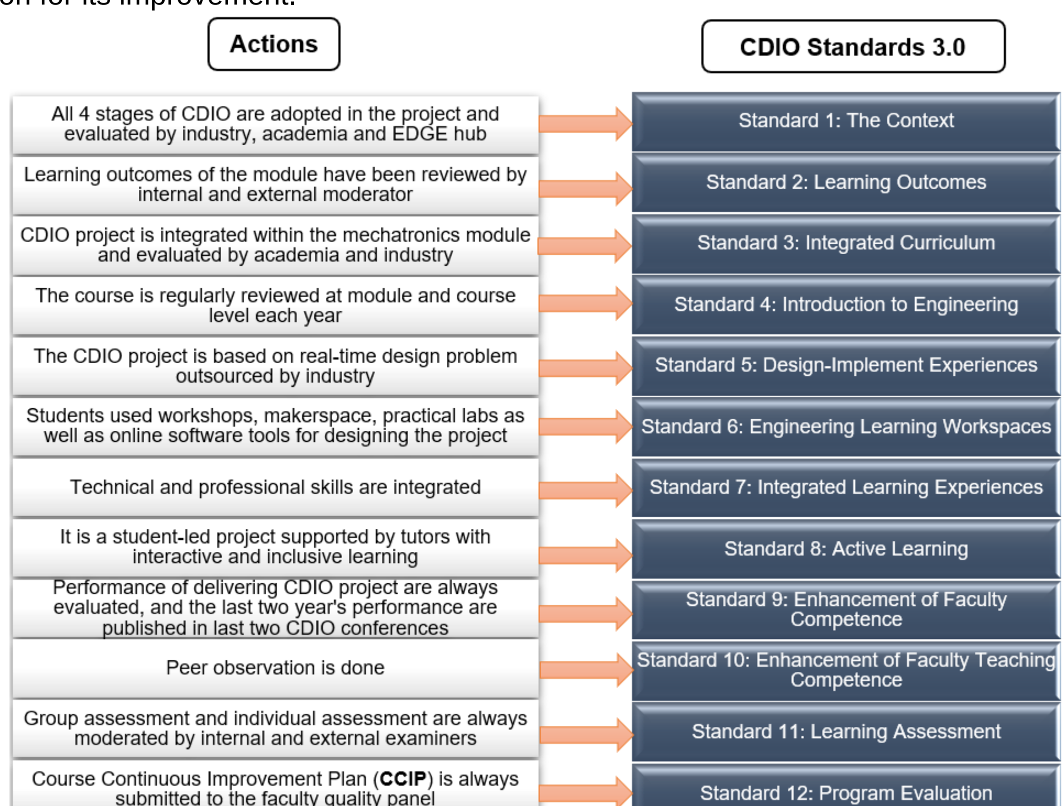


Figure 1. Mapping of actions with CDIO standard 3.0

We have been teaching one such CDIO project-oriented module ‘Professional Engineering Project (with Mechatronics) in the last academic year for the Level 4 (first year) students. The CDIO project was outsourced by a local company Barton Marine, designers and manufacturers of products for sailing boats. The task was focused on resolving an existing real-world problem in the sailing industry. Therefore, students require technical knowledge to come up with innovative ideas through critical thinking. However, they also need competency in hands-on skills, engagement in teamwork and project writing skills to document the final project for making it presentable in front of the industrial partner.

Due to the new COVID-19 guidelines in the UK higher education sector, a hybrid learning platform where a combination of online and campus-based learning has been adopted in all higher education institutions (Peimani & Kamalipour, 2021). Along with other universities, courses in CCCU have been shifted to a blended learning platform. In the blended learning approach (Lapitan Jr, Tiangco, Sumalinog, Sabarillo, & Diaz, 2021), both online and face-to-face sessions have been implemented in the teaching and learning framework for lecture and practical sessions respectively. Due to a large cohort of students, lecture sessions were scheduled during online sessions whereas students were divided into a small group of 15-20 students to attend the practical sessions in-person with tutors and technical staff on campus. Based on the following learning and teaching strategies, an optimal arrangement of blended learning approach facilitated the CDIO project effectively: online lectures and practical sessions for 8 weeks until Easter holiday, face-to-face practical sessions on campus for two weeks after Easter (6 hours a day and continued for four days per week). The schedule of the online and face-to-face sessions was organised in a way so that allotted time could be utilised appropriately and learning outcomes will be met whilst maintaining COVID-19 restrictions. Lecture classes had been delivered in two different sessions: in technical lecture session, students were taught about different technical knowledge and skills related to mechatronics for developing the CDIO project whereas in professional lecture session, students were taught about professional attributes such as teamwork, ethics, sustainability, health and safety, project planning, report writing etc. for supporting the CDIO project. Also, separate one-to-one session was provided to individual students for clearing doubts and project guidance.

Online practical sessions were mainly planned for students to develop their solution of the CDIO project. During this time, students came up with innovative solutions for the CDIO problem and designed them using different software tools. Face-to-face practical sessions were then delivered after Easter so that students could manufacture the components and develop the prototype. To build the hardware model of their CDIO project, students have used several pieces of mechanical equipment during face-to-face sessions. They had also undergone health and safety training for handling equipment and operating these safely. Hence, the arrangement of blended learning (Figure 2) has not only maintained the CDIO projects in flow with COVID-19 restrictions but also improved the hands-on skill, critical thinking and teamwork ability of students. In this module, all student groups were encouraged to come up with their individual innovative ideas to design and develop the CDIO project. Following the strategy, conceive and design part of the CDIO project were completed during online sessions whereas the project was implemented and operated during the face-to-face sessions. During the conceive stage, students defined the aims and objectives of the CDIO project based on their proposed solution. After that, students performed a thorough investigation (literature review) on the existing projects (relevant to the CDIO problem) to know more about their advantages and limitations and drew their conclusion to identity the required properties needed to be incorporated in their proposed solution. In the next stage, the overall methodology of the project was proposed and described by each group with the required product design specification sheet (Stoll, 1999), technical and commercial attributes. As a part of literature research, students accumulated the specifications of the CDIO project with ideal value, target and achieved values where ideal value was determined from the research on existing projects, target values were decided by the cost, time and several other factors whereas achieved values were recorded after developing and testing the prototype. All these processes were completed during online sessions.

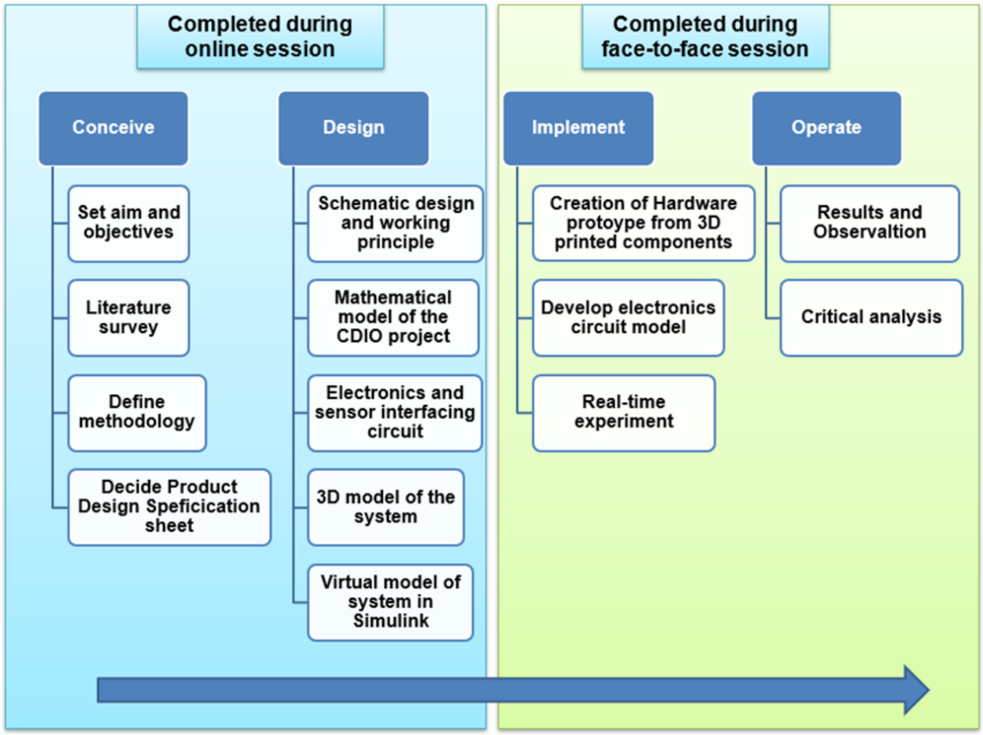


Figure 2. Pathway of implementing the CDIO project

During the design stage, students developed the design framework of the CDIO project and its associated outputs from a technical perspective such as schematic design, mathematical model, 3D model, electronics circuit, sensor interfacing circuit, virtual model. A Gantt chart with an appropriate timeline was provided to students. Different types of software were used to develop those models such as Fusion360 for creating 3D models, Tinkercad for designing the electronics circuit and sensor interfacing circuit, Arduino studio for embedding code in Arduino board, MATLAB and Simulink for creating a mathematical and virtual model of the proposed solution. The advantage of using these software tools was that students could furnish those tasks online, evaluate the model virtually before finalizing the hardware. Besides, learning these software tools made their portfolio stronger for a career goal.
For implementing the CDIO project, face-to-face sessions were arranged so that students could manufacture the hardware parts of the CDIO project. During operate stage, a comparative analysis was drawn by students between the real-world results, simulation results and theoretical results. Finally, all students submitted their CDIO project report (mentioning individual contribution in the project work) and presented as a group.

GROUP PROJECT SESSIONS

The CDIO project was based on a group-based task where 3 to 4 students were involved per group in providing an innovative solution to a real-world engineering problem. Although it is a group project, students found it difficult to manage teamwork during online sessions for several reasons such as technical, physiological and mental wellbeing issues (Savage et al., 2020). Several students suffered from COVID-19, therefore they could not attend several sessions and missed important discussions of the project work. Staying at home and disengagement with peers and friends in person have made the majority of students mentally not well. Students with prolonged medical illness (legionnaires disease and mental health issues) and learning disability (dyslexia, AHDD, and autism) were sometimes unable to convey their opinion properly during online sessions and a miscommunication gap occurred. It should be noted that 20% of the cohort have learning support plans, typically for a learning disability (dyslexia, AHDD or autistic). Furthermore, we are aware of a number of students not yet formally diagnosed. Students not in University accommodation in Canterbury, surrounding area or countryside locations faced challenges with internet connectivity (as Kent is poorly broadband served). Therefore, the communication was often interrupted during the group sessions. In addition, students' hardware mic and camera would function with MS Teams, but not with Blackboard Collaborate, however chat functions were operable. Another important issue was the lack of IT equipment among the students from low economic backgrounds, preventing them to attend the scheduled online sessions with other students.

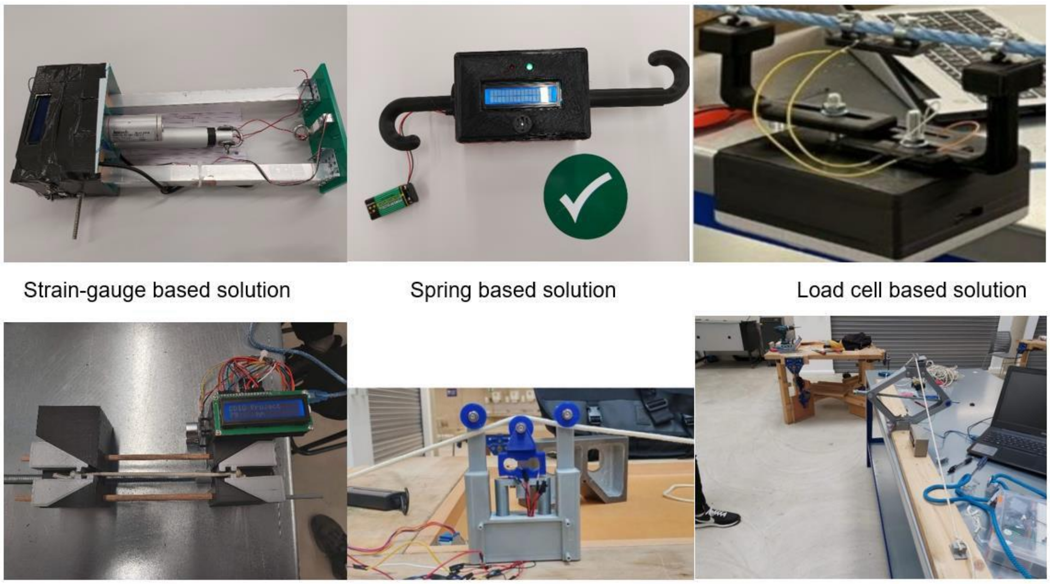
In order to incorporate the seed of teamwork among the students during online sessions, breakout groups were created in Blackboard Collaborate platform for facilitating teamwork, nurturing constructive discussion and generating critical thinking. Even disabled students had been treated in the same way (with extra support from tutors) as they joined a usual group and participated in the group task. Constructive criticism of ideas was always helpful for a group project. A discussion room was created in Blackboard for sharing weekly progress and doubts, and tutors reviewed those reports by providing constructive comments to improve them further. The whole task was divided into several sub-tasks and distributed among the group members so that each team member in the group had the responsibility to complete a specific part of the project and shared the outcome with others. For example, the person who did the 3D modelling of the project during online sessions, will manufacture the components using 3D printer and assemble them to develop the prototype during face-to-face sessions. Although the subtasks were assigned to each person in a group, they could seek assistance from team members while doing their part of the job, enhancing their ability to pursue teamwork and partnership in the project. To support the students with physical and mental health issues, the student-wellbeing team functioned efficiently and provided the required help. Students also benefited from the CCCU hardship fund to buy IT equipment for learning.

ONLINE ASSESSMENT STRATEGY

The assessments associated with the CDIO project were designed to judge their technical skills as well as several professional attributes such as critical thinking, hands-on skill etc. In the end of the CDIO project, students submitted a group poster where they described the aims, methodology, design, manufacturing, and testing results of the CDIO project. All team members in a group contributed to designing the poster and presented it in front of a panel. Due to COVID-19 restrictions, the poster presentation was organised online. Finally, students also submitted an individual CDIO project report on producing their novel idea to overcome the issues raised by the industry. The project report included the design model, test, and results in detail.

CDIO PROJECT OUTCOME AND PERFORMANCE OF STUDENTS

The project was based on designing and developing a digital, portable and affordable solution for measuring tensile strength. The project ideas (Figure 3) pursued by the students were brilliant, innovative and diverse consisting of spring based linear displacement to transform tensile strength into digital scale, ultrasonic sensor displacement in terms of measuring continuous tensile force, encoder based angular displacement due to tensile force, strain gauge-based solution for measuring tensile strength, force sensor-based solution for measuring tensile strength etc along with different types of mechanism. Their outcome of those CDIO project was satisfactory as per the quality and standard.

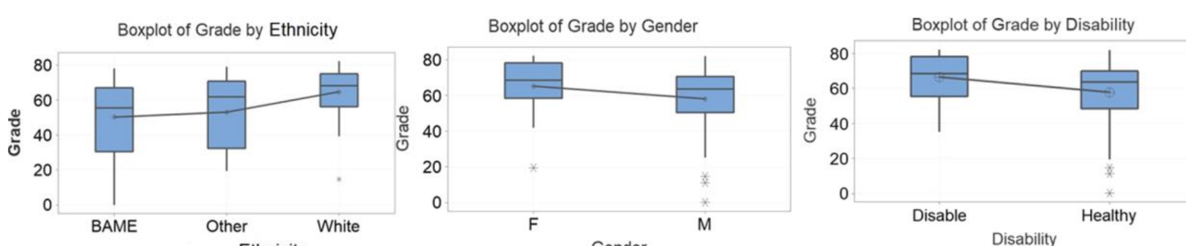


Strain-gauge based solution   Spring based solution   Load cell based solution

Ultrasonic sensor based solution   Load cell based solution   Force sensor based solution

Figure 3. Innovative solutions proposed by students

Along with the outcome of the prototype, both group poster and individual CDIO project report of the students were assessed for evaluating their performance and grades. The student grades have been analysed through Minitab® (statistical software). There were 72 students enrolled in the module, however, 8 students did not engage in the module and their marks are excluded. Hence, we have only considered the marks of 64 students for the analysis. The first-time overall pass rate is relatively high (86%). The average grade of the module is 59.66 (excluding missing marks) and the standard deviation is 18.51 which is a satisfactory outcome.



Statistics	BAME	Other	White
N	15	9	40
Mean	50.2	53.056	64.688
Standard Deviation	24.265	21.156	13.417
Minimum	0	19.5	14.75
Maximum	78	79	82.25

(a)

Statistics	F (Female)	M (Male)
N	14	50
Mean	65.214	58.1
Standard Deviation	17.659	18.617
Minimum	19.5	0
Maximum	82.25	82

(b)

Statistics	Disable	Healthy
N	13	51
Mean	66.596	57.887
Standard Deviation	14.068	19.199
Minimum	35.25	0
Maximum	82.25	82

(c)

Figure 4. Performance analysis of students based on several factors

The grades of the students have been investigated further based on ethnicity (Figure 4a), Gender (Figure 4b) and disability (Figure 4c) using box plots. Figure 4a shows that the average grade of the white students is 64.69 which is comparatively higher than that of BAME (black, Asian and minority ethnic, 50.2) and students of other ethnicities (53.06). Also, the grades of white students are distributed close to the mean value whereas the spread of grades for BAME and students of other ethnicities is larger.

The grades achieved by female students (mean value: 65.21) are on average higher than male students (mean value: 58.1), as shown in Figure 4b. Due to the inclusive learning framework, disabled students have performed well in the CDIO project, the average grade of disabled students is 66.59.

A high pass rate of students has been reflected in all types of student cohorts, for example, the pass rate of female students is 98.43%, for BAME students is 93.75% and for other ethnic students is 95.31%. The overall pass rate of disabled students is also 98.43%. The performance of students has been further investigated using box plot of groups where student cohorts have been divided into disabled and healthy around gender, and ethnicity around gender. Figure 5a shows that disabled students of both male and female gender have achieved higher grades compared to health students. Similarly, male and female white students have achieved higher grades compared to other ethnicities and BAME students (Figure 5b). It also shows that female BAME students actually performed well and achieved good grades, however, male BAME students faced difficulties and need support (Figure 5b).

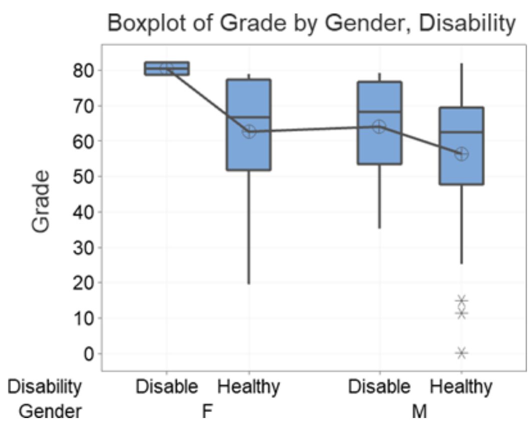


Figure 5a. Performance of disabled students based on gender

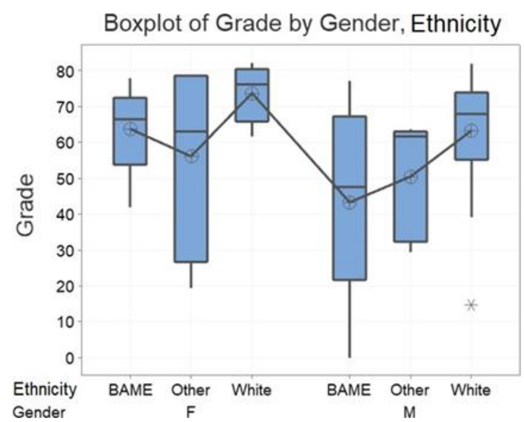


Figure 5b. Performance of different ethnicity students based on gender

The students' grades have been distributed by students' age and shown in the main effect plot (Figure 6). It shows that students within the age group (> 25 years and < 20 years) have achieved comparatively performed well. On the other hand, the amount of variation in the grades for 20 – 25 years students are significantly higher compared to other age groups.

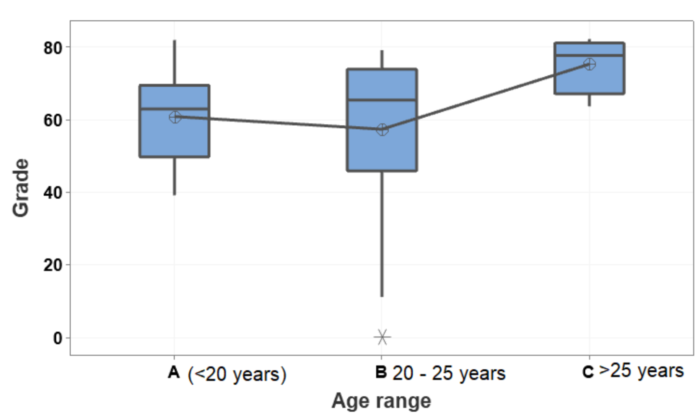


Figure 6. Distribution of grade over the age group of students

A survey with a qualitative questionnaire was conducted among the students to capture their experience in the module and how the project helped to grow their professional and technical skills. The survey also included the future recommendations from the students related to the engagement of employability skills using CDIO projects. The overall experience was above the satisfactory level from students' perspectives. Feedback from students was positive, helpful and informative. The arrangement of CDIO project sessions was efficient in terms of fulfilling students' expectations and it was also reflected in their final assessment. There are a few improvements required in several areas such as time allocation for completing the project, industrial engagement, engagement of disabled students in group work, blended learning approach, conflict of interest in a group project, enhancing outreach and networking. We have also received positive feedback from Barton Marine regarding the outcome and the standard of the project.

CONCLUSION

The main aim of introducing the CDIO project in this module was to enhance the critical thinking, hands-on skills, teamwork and report writing skills of students. Most of the aims have been already achieved through optimal use of blended learning, arrangement of supporting workshops, problem-based learning and so on. Several areas for improvement have been identified, including enhancing the engagement of students with learning disability, improving the industrial engagement and allowing sufficient time for practical work. The survey outcomes consisting of students' feedback on their involvement and experience (innovative ideas development, way of completion, level of outcome, project planning) in finishing the CDIO project were satisfactory and have supported the plans for the future delivery of this CDIO project module. In this CDIO project, students have also implemented previously gained knowledge that was taught in previous modules, as per CDIO Standard 3. For example, students learned Fusion360 and Tinkercad in the previous semester. However, they used Fusion360 for designing the 3D model of the CDIO project and Tinkercad for designing its electronics model. Due to the involvement of industry, it did not merely appear as an academic project as students were engaged to the industrial platform, talked to industrialists, and created an understanding of the outside engineering world. Working in a multidisciplinary CDIO project, students became familiar with the overall structure of a system and its associated components and their functions. This helped to incorporate the problem-solving skills so that students could resolve real-life engineering problems using their mechatronics knowledge.

Several future action plans have been considered in the reflecting stage in order to overcome the current limitations. For example, the CDIO project can be divided into two segments between two levels (Foundation year and Level 4) where basic parts will be designed and developed by foundation year students and Level 4 students will work at the advanced level of the project. The students from both levels will be working together to present the project, in a way that Level 4 students can supervise the foundation year students and thus enhancing teamwork and leadership capability. Due to COVID-19 restrictions, it was not possible to keep face-to-face interaction with the industry. When the situation will become normal, an industrial visit will be planned for students to enhance their engagement. It is always difficult to integrate disabled students in a group project due to their communication issues with other group members. The best practice will be to provide extra support for them so that they would not fall apart and lag behind other team's members. Students will be encouraged to unite irrespective of their abilities and disabilities in order to manage the group work. In the last academic year, we had to keep block face to face practical sessions to maintain a certain number of students in a lab.

To improve the students' learning experience, weekly practical sessions will be arranged for students as students can follow weekly lectures with relevant practical sessions rather than doing it after five to six weeks. Besides, all the academic support, more individual support should be provided to students suffering from mental and physical wellbeing. Although several learning support arrangements are already in place for disabled students, the university should still provide extra student-support such that students will be more confident during their studies.

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BIOGRAPHICAL INFORMATION

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Dr Najah Battikh is currently a Lecturer and Course Director for Chemical Engineering at the School of Engineering Technology and Design, Canterbury Christ Church University, UK. Najah has a degree in Chemical Engineering, MSc in Embedded Systems Engineering and PhD in Chemical Engineering. Najah's main research interests include the use of optical techniques in characterising the crystallisation process as also how this can be utilised in combination with rapid heating and cooling to control the crystallisation process in chemical and pharmaceutical industries as well as water treatment, desalination, and the removal of microplastics from water. She is also interested in Engineering Education Research and CDIO based project activities.

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