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A Comparison of Psychomotor Domain Assessment in Water Engineering Laboratory between F2F and ODL

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Abstract

Pandemic has changed teaching, learning and assessment (TLA) methods in conducting remote learning during open distance learning (ODL). This scenario has switched physical learning to virtual learning worldwide including UiTM. Ideally it has a positive impact in the academic landscape, however there are challenges for technical programmes which assess psychomotor domain including Diploma in Civil Engineering at UiTM Pasir Gudang. This paper is a preliminary study to compare the student performance before pandemic (Sept 2019-Jan 2020) and during pandemic (Sept 2020- Jan 2021) in addressing psychomotor domain for laboratory courses (water engineering laboratory). Result shows a positive impact on student performance during ODL. However, there is a flaw and weakness in assessing psychomotor domain during ODL. Hence monitoring on TLA should be done for the betterment of TLA for future and continual quality improvement (CQI) is necessary to ensure the quality of teaching for laboratory courses.

Keywords: Remote Learning, Psychomotor Domain, Engineering Education, Laboratory Assessment

Introduction

The development in technologies nowadays is growing rapidly. The application of current scientific knowledge for practical purpose is very important especially in industry. To keep up with the high demands in the industry, graduate students are required to adapt with the technologies and the technical skills. A certificate of accreditation from the Engineering Technician Education Program Accreditation Standard (ETAC) is required to produce qualified graduates. The accreditation ensures that graduates of the program meet the minimum academic and practical requirements for registration as engineering technicians for diploma level (Engineering Technician Education Programme Accreditation Standard, 2020)

Various domains of learning are classified by Bloom's Taxonomy (Bhargav et al., 2016). In designing curriculum for engineering courses, Program Outcomes (POs) were developed using three domains of Bloom's Taxonomy: cognitive, psychomotor, and affective. There are

twelve (12) POs should be mapped through course outcome in ensuring student being able to develop generic skill as an assistant engineer upon graduation after 3 years of Diploma in Civil Engineering (EC110) in UiTM Pasir Gudang.

Water Engineering Laboratory is one of the courses in Diploma in Civil Engineering of UiTM. The teaching and learning, and assessment for this course is based on psychomotor domain since it involves laboratory work. Psychomotor skill is very important to prepare students to practice engineering (Daud et al., 2018). Student's technical skills can be improved and nurtured through psychomotor domains. Psychomotor learning includes physical skill demonstrations in the classroom, workshop, and laboratory with equipment or tools (Ahmad et al., 2018). The use of physical equipment provides students the opportunity to develop practical laboratory skills, including troubleshooting, and to experience the challenges that arise when planning experiments that require careful setup of equipment and observation (Jong et al., 2013).

It has been shown in previous research that laboratory experiments assist students in practicing technical skills. Students will have the opportunity to practice and develop their practical skills through laboratory experiments (Baharom et al., 2015). It is essential to create a set of assessments that enable students to be measured according to different aspects of their psychomotor ability. To meet the program outcome, a comprehensive methodology and appropriate assessment rubrics for the course are developed and implemented in traditional face to face (F2F) class.

However, following Covid-19 outbreak in Malaysia, Institutions of Higher Learning were forced to convert their normal F2F teaching and learning to ODL. An immediate action needs to be taken to adapt with the situation. This paper is a preliminary study to compare the student performance before pandemic (Sept 2019-Jan 2020) and during pandemic (Sept 2020- Jan 2021) in addressing psychomotor domain for laboratory courses for Water Engineering Laboratory. This paper discusses the teaching and learning method, and assessment during normal F2F class. Issues encountered in the teaching and learning process and assessment of psychomotor skills during ODL, and immediate measures implemented during the semester to guarantee learning outcomes are achieved also being discussed. The objective of this paper is to compare student's PO attainment related to psychomotor domain assessment between F2F and ODL.

Psychomotor Domain in Water Engineering Laboratory

This course reinforces concepts introduced in fluid mechanics, hydraulics, hydrology, and water quality. Throughout the semester, students are required to conduct experiments, analyze, and prepare laboratory reports. The teaching methods for Water Engineering Laboratory are through laboratory work and practical classes. To developed student's psychomotor skills, at the end of the course, students should be able to construct the experiments, data analysis and interpretation methods related to basic fluid mechanics, hydraulic, hydrology and water quality using standard test and measurement. Course outcome and program outcome which is mapped to the psychomotor domain is shown in Table 1.

Table 1
Course Outcome and Program Outcome for Water Engineering Laboratory

Course Outcome (CO)	Program Outcome (PO4)	Taxanomy Domain	Assessment
Construct the experiments, data analysis and interpretation methods related to water engineering laboratory using standard test and measurement	Conduct investigations of well-defined problems; locate and search relevant codes and catalogues, conduct standard tests and measurements.	Psychomotor	Practical Test 1 (PT1) Practical Test 2 (PT2)

In traditional F2F class, teaching and learning activities are conducted in Hydraulics Laboratory and Wastewater Laboratory for two hours per week. Since this course reinforces in basic fluid mechanics, hydraulics, hydrology and water quality, the activities need to be performed in two separate laboratories due to different apparatus required. There are 11 laboratory activities throughout the semester. During the laboratory activities, lecturer will explain learning outcome for the week, the objective of each laboratory, theory, apparatus, procedures, data that need to be acquired and analyzed the result. Then lecturer will demonstrate on how to assemble the apparatus, run the experiment, and collect data needed. This step is very important as student need to conduct their own experiment by group as their psychomotor skills development. Student's psychomotor skills in this course will be assess in practical tests which are divided into two, practical test 1 and 2. Each practical test will carry 20% from total evaluation marks. Normally, practical test 1 will be conducted in week 8 and practical test 2 in week 14 of the semester. Practical test is done individually. During the practical tests, students are expected to identify and assemble apparatus needed to conduct the laboratory activity, perform the procedures, and record the correct data from the experiment.

Challenges of Psychomotor Domain in ODL

Since the transformation period was so short, there were some challenges in adapting methods for teaching and learning, and assessment that need to be conducted for ODL method from traditional F2F methods. UiTM Cawangan Johor Kampus Pasir Gudang was totally shut down for physical learning in campus since the implementation of movement control order (MCO) starting on March 2020. Therefore, students who enroll this course for Sept 2020 – Jan 2021 are not allowed to be in campuses. Teaching and learning delivery method for all courses were through fully ODL. Adjustment needs to be done to accommodate with the situation. It is very important for the lecturer to have a deep understanding of what needs to be assessed and developed during engineering laboratory courses (Seth & Haron, 2016). ODL learning requires students to be proactive and well-equipped with technology devices (Chiew et al., 2021). In ODL, the lecture can be done in synchronous and asynchronous. Synchronous learning virtual classroom allows educators and students to collaborate and interact in real time (Amir & Borhan, 2022) using online tools such as Microsoft Teams, Google Classroom, Webex and many more. Asynchronous learning is opposite with synchronous where the learning activities does not happen in real time. It is more flexible where students can learn in their own time using materials that being uploaded by the lecturers. The challenge for the lecturer was to create teaching and learning delivery method that align with psychomotor domain's taxonomy level as teaching methodology for

this course before pandemic was through laboratory activities. As mentioned in guideline, (Board of Engineers Malaysia, 2020), delivery method that can be considered is to post or transport the components, materials and tools required by student to carry out the experiment by their selves. This method is impossible to achieve as this laboratory required big apparatus such as hydraulic bench, open channel flume, pump, turbine, and chemicals solution. Other possible method for consideration is via pre-recorded video of the actual demonstration of experiments by lecturer. Students can visualize the entire experimental process and its environment through video-based activities that provide an overview of a real laboratory (Gamage et el., 2020). The most challenging part was to record the whole procedure for all laboratory activities in a way that students can understand the theory of the experiment, recognize the apparatus required, run the experiment with correct procedures, collect data, analyzed the results, and finally produce final laboratory report for each experiment. Data for each experiment was given by lecturer since student did not perform the experiment by themselves. Practical tests were conducted via interview session individually using suitable platform. Each student will be given fifteen to twenty minutes to complete the test. During the interview session, students must answer question related to laboratory activities. Marks will be given according to rubrics for practical tests. The bigger challenge here was for students to explain and elaborate the experiments without they perform the experiment on their own. Pre-recorded laboratory procedures could assist students in preparing for tests (Pintaric & Kravanja, 2020).

The inability to interact F2F between students and lecturer also contribute to challenges during ODL especially for course that based on psychomotor domain activities. Although students were able to communicate with their lecturers via online platforms during synchronous or asynchronous learning, there was still no F2F interaction between them and their lecturers. It is difficult for lecturers to make sure students really can grasp what their learn through the video of experiment provided by the lecturers. In traditional F2F class, lecturer can observe and monitor how students conduct the experiment, at the same time guide them during the process if needed. Some students may loss of motivation to give fully commitment to online class due to lack of F2F interactions with group members and lecturer. Some students may face difficulties to staying focus for hours online (Debacq et el.. 2021). Internet connectivity can also contribute to student's motivation to commit with ODL. Some maybe resided in rural areas that facing poor internet connectivity or could not afford to provide internet data. By given the pre-recorded video, students with this kind of problem can watch and learn later once they have the internet connection.

Methodology

This study was conducted for two semesters. For semester Sept 2019-Jan 2020 (Semester 20194) with 225 students registered for Water Engineering Laboratory course, which is represent semester before pandemic Covid-19. During Semester 20194, teaching and learning activities conducted as fully traditional T&L face to face. This study compared semester 20194 with semester 20204, where semester 20204 (semester Sept 2020-Jan 2021) is a fully online distance learning (ODL) during pandemic Covid-19. On semester 20204, 268 students registered for Water Engineering Laboratory course.

Water Engineering Laboratory is a subject for year three students in the School of Civil Engineering at the University of Technology MARA, UiTM. This course deals with the laboratory works on fluid and hydraulic areas covered in previous subject in year two. The

assessment on this course covers practical tests, observation of laboratory works and laboratory reports.

Simpson (1972) explain the taxonomy of educational objective in psychomotor domain should be assess according to their level of difficulties such as perception (P1), set (P2), response (P3), mechanism(P4) and complex over response (P5). These educational objectives were used by educators to develop curriculum materials as guidelines for evaluation of programme outcomes.

Teaching and Learning Method during F2F and ODL

All laboratory works for courses in the School of Civil Engineering were conducted based on an open-ended laboratory (OEL) system. The open-ended system for the laboratory is conducted where the experiments are not fully guided as compared to the traditional laboratory method. By incorporating OEL in laboratory courses, students can apply their innovative and creative thinking to solve problems given by conducting experiments. For the Water Engineering Laboratory course, the open-ended laboratory levels are Level 0, Level 1 and Level 2, suitable for the students' level for year three at the programme level. Level 0 is known as the traditional method for teaching and learning for laboratory class, while Level 1 and Level 2 are known as an open-ended laboratory with 33% and 66% levels of openness respectively. For OEL's Level 1, students were given preamble, problem statement, and ways and means while for OEL's Level 2, only preamble and problem statement were given to students as references before conducting the experiments. For Level 1, the data to be obtained and analysed were not guided in the laboratory manual. Students in a group need to explore what data is to be obtained and analysed based on the problem statement, objectives and equipment in the laboratory. For Level 2, it is similar to Level 1 with additional where students need to identify the correct apparatus for the experiment and propose relevant procedures with regard to the intended experimental works. The proposed procedures should consider the availability of the apparatus, chemical and materials in the laboratory.

Students were given briefing on OEL in the early semester to ensure students fully understand OEL's system. A list of laboratories was given in advance based on the level of openness so that students will be prepared every week before conducting laboratory. The laboratory manual is prepared based on the openness level in OEL for this course. Students worked in groups of a maximum of four students following guidelines by ETAC to complete the experimental works and laboratory reports.

During laboratory session, laboratory conducted with briefing from lecturer on early session based on experiment to be conducted. Then students will conduct experiments in groups of four students. Due to pandemics starting on March 2020, method of teaching and learning (T&L) was adjusted to align with ODL approach.

On ODL session, method of teaching and learning replace by lecturer give recorded video for demonstration of laboratory work to students. Recorded videos of conducted laboratory were recorded by lecturers using laboratory's facilities in campus as shown in Figure 1 for weekly basis according to lesson plan. During each laboratory session, the lecturers conduct briefing and explain the experiments based on recorded video to students. Furthermore, raw data that supposedly obtained from laboratory works were given by lecturers to students, so that students can proceed with result analysis, discussion and conclusion to complete their laboratory reports. Since this paper is focused on psychomotor

domain therefore, discussion will be based on practical tests which are conducted for two times as practical test 1(PT1) and practical test 2 (PT2).

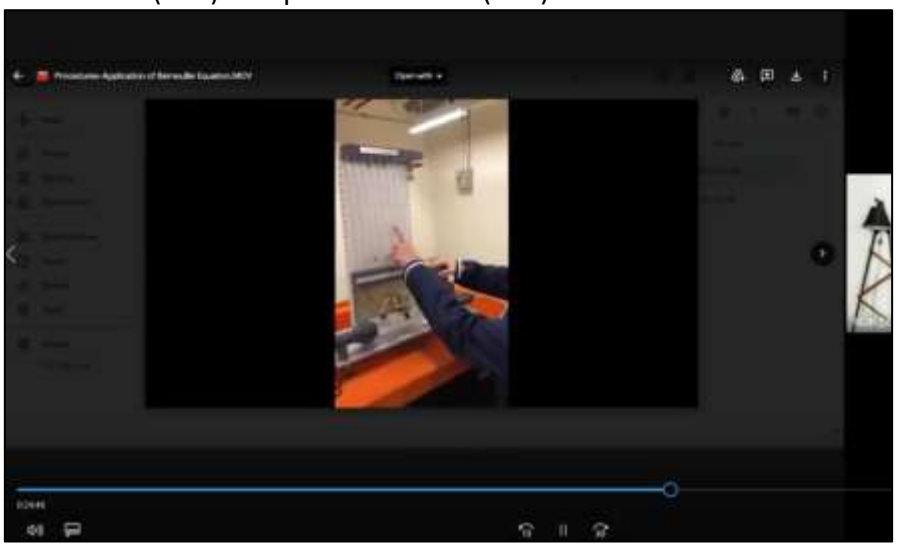

Figure 1: Screenshot of recorded video given to students during pandemic Covid-19 (Semester 20204)

Assessment Tools during F2F and ODL

Assessment method and percentage distribution for this course is shown in Table 2. Basically, there are four types of assessments measured which are laboratory reports, assignment, observation, and practical tests. This course mainly assesses affective and psychomotor domain. The psychomotor domain on this course measured the ability of students to investigate well-defined problems through experiments conducted following the standard tests and measurements.

Table 2
Distribution of Assessments for Water Engineering Laboratory

Assessment Methods	Percentage Distribution(%)
Laboratory reports	30
Assignment	10
Observation	20
Practical Tests	40

Since this paper is focused on psychomotor domain; therefore, discussion will be based on practical tests which are conducted two times as practical test 1 and practical test 2. Practical tests are conducted two times for each semester, where practical test 1 and practical test 2 are conducted on week 8 and week 14 respectively. Practical test 1 assesses laboratory work from week 2 until week 7 of T&L, while practical test 2 assesses laboratory work from week 9 until week 13.

During semester 20194 before Covid-19, practical tests were conducted face to face in the laboratory where students need to conduct laboratory works based on rubrics. As Covid-19 outbreak and MCO occur, laboratory conducted with full ODL on semester 20204. Therefore, assessment of practical tests was conducted through an online platform. Lecturers conducted practical tests with students individually, students will answer questions verbally through online meeting as shown in Figure 2. Practical tests are conducted verbally online

due to the limited resources available for preparation and demonstration. As this semester is fully ODL and students are at home, the laboratory works for this course using chemical and machinery resources that could not be simulated by existing material at home. A comparison of assessment delivery for semester 20194 and 20204 can be found in Table 3.

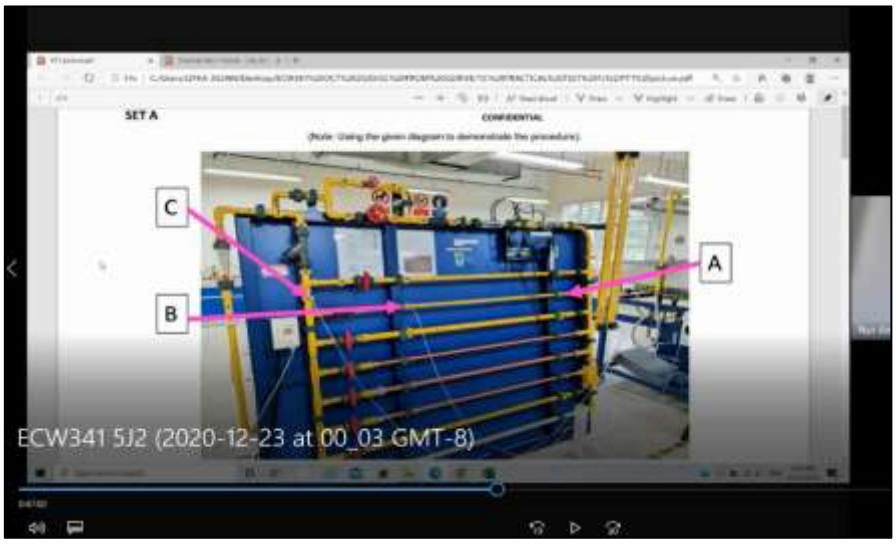

Figure 2: Screenshot of practical test conducted with students during pandemic Covid-19 (Semester 20204)

Table 3
Comparison assessment delivery before and during pandemic Covid-19

Assessment of Psychomotor	**Before pandemic Covid-19**	**During pandemic Covid-19**
Practical tests	Practical tests conducted in the laboratory face to face	Practical tests conducted online through any suitable platform

Table 4
Psychomotor rubric for Water Engineering Laboratory

DOMAIN	SCALE					
	0	1	2	3	4	5
P1 (Perception) Recognize the right apparatus/reagents required to conduct the particular laboratory test. **(Hydraulics Laboratory Equipment).**	Unable to recognize /choose the apparatus/reagents required to conduct the particula	Able to recognize/ choose the apparatus /reagents required to conduct the particular laboratory but required	Able to recognize/ choose the apparatus /reagents required to conduct the particular laboratory completely with	Able to recognize/ choose the apparatus /reagents required to conduct the particular laboratory completely without any help	-	-

	r laboratory.	major help.	minor help			
P2 (Set) Display the right use of PPE for study/laboratory test. **(lab coat-properly button and safety shoes, gloves, goggles-option)**	Unable to display the right use of Personal Protective Equipment (PPE) to the particular study/laboratory test.	Able to display the right use of Personal Protective Equipment (PPE) to the particular study/laboratory test but incomplete.	Able to display the right use of Personal Protective Equipment (PPE) to the particular study/laboratory test completely.	-	-	-
P3 (Guided response) Demonstrate on assemble the apparatus/equipments for particular study/laboratory test **(Equipment Set Up). (e.g; Hydraulic Bench Setup)**	Unable (0-10%) to assemble the apparatus/ equipments for particular study/ laboratory	Able to assemble the apparatus /equipments for particular study/laboratory but (11-30%) accurately set up.	Able to assemble the apparatus /equipments for particular study/laboratory but (31-50%) accurately set up.	Able to assemble the apparatus /equipments for particular study/laboratory but (51-79%) accurately set up.	Able to assemble the apparatus /equipments for particular study/laboratory (81-100%) accurately set up. without competence and confidence	Able to assemble the apparatus /equipments for particular study/laboratory 81-100%) accurately set up with competence and confidence
P4 (Mechanism) Demonstrate on how to run	Failed (0-10%) to run the experim	Unable (11-30%) to run experime	Able (31-50%) to run experime	Able (51-79%) to run experime	Able (80-100%) to run experime	Able (80-100%) to run experime

the study/laboratory work. **(Note: Student must demonstrate all the steps accordingly the laboratory manual)**	ent/tasks.	nt/tasks but fail to follow all procedure (missed almost all steps)	nt/tasks but fail to follow all procedure (lacking)	nt/tasks but fail to follow all procedure (lacking)	nt/tasks as procedure without competency and confidence.	nt/tasks as procedure perfectly with competence and confidence
P5 (Mechanism) Demonstrate on recognizing the study/laboratory work and expected data measurement /representation. **Measurement of result (type of data and presentation)**	Able (80-100%) to construct and conduct the experiment/tasks as procedure without competency and confidence but Unable to recognizing the expected result of the experiment	Able (80-100%) to construct and conduct the experiment/tasks as procedure perfectly with competence and confidence and	Able (80-100%) to construct and conduct the experiment/tasks as procedure without competency and confidence but Unable to recognizing the expected result of the experiment	Able (80-100%) to construct and conduct the experiment/tasks as procedure perfectly with competence and confidence and	Able (80-100%) to construct and conduct the experiment/tasks as procedure without competency and confidence but Unable to recognizing the expected result of the experiment	Able (80-100%) to construct and conduct the experiment/tasks as procedure perfectly with competence and confidence and

Practical tests were assessed individually based on rubrics provided based on the psychomotor domain. The individual assessment contributed 40% for students and consists of two practical tests. Table 4 shown psychomotor rubrics for both practical tests.

In this study, assessment tool has been prepared with rubric and aligned with PO4 for psychomotor. Then the marks obtained for each PO were analysed using i-RAS for each student. Throughout ODL's semester, T&L differs to semester F2F on how laboratory session and assessment psychomotor were conducted while syllabus covered, and type of assessments remain the same.

Students' Performance during Face-to-Face Teaching and Learning Semester (20194)

The performance of psychomotor skill of students is assessed by students' grade for a particular Course Outcome (CO) and Program Outcome (PO) to measure their key performance indicator (KPI) stipulated by School of Engineering UiTM, i.e., students' grade greater than 50% or grade C. Figure 3 shows students' grade attainment for September 2019 – January 2020 (20194) during Face-to-Face teaching and learning. From the figure shows that 100% of the total students were able to achieve the KPI, where the minimum grade achievement is B- (scored marks greater than 60%) and 80% of total students managed to obtain marks of 80% and above (grade A).

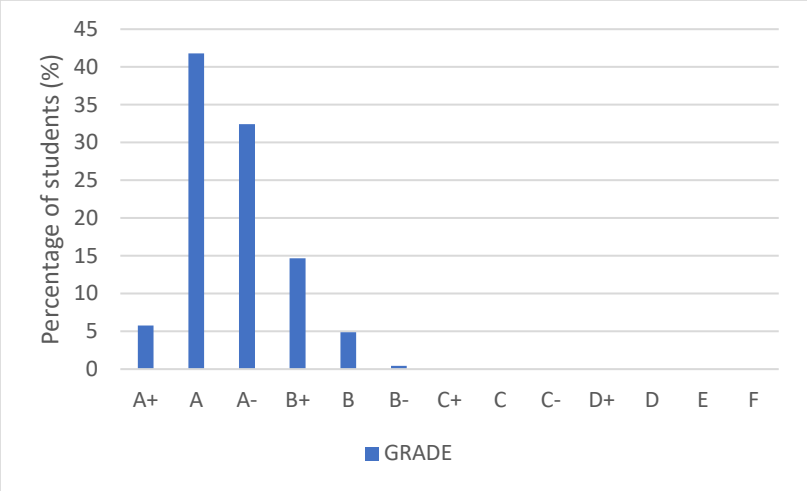

Figure 3: Students' Grade Attainment during Face-to-Face Teaching and Learning

The percentage of students' grade attainment based on Practical Test 1 (PT1) and Practical Test 2 (PT2) which measured the taxonomy domain (P4), and Program Outcome number 4 (PO4) are shown in Figure 4. The Performance Criteria Matrix (PCM) from iRAS (Revolution on Assessment for Student Monitoring System) template can be used to categorize students' performance according to KPI categories, as shown in Table 5. Based on Table 5 and Figure 4, 49.3% of total students achieved 'good' KPI category and 50.7% of total students were in the 'excellent' category.

Result indicated that most students were in the 'excellent' and 'good' categories, shows that students were able to demonstrate almost all psychomotor skills necessary to conduct the experiment during PT1 and PT2. The students were able to solve the given problem based on scenario, demonstrated the proper use personal protective equipment (PPE) for conducting laboratory test, set up the equipment within the given timeframe, demonstrate and conduct experiment with more than 85% completion, and demonstrate care and respect for equipment with minimal or no guidance. The results of both assessments also indicate most students were able to gasp the relevant practical skill during PT1 and PT2.

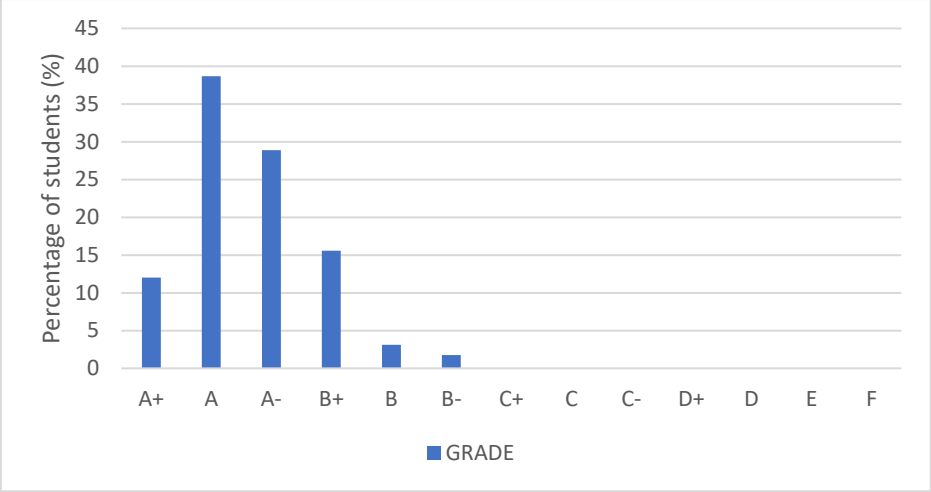

Figure 4: Students' Grade Attainment of Psychomotor Domain (PT1 and PT2)

Table 5
POs Performance Criteria Matrix (PCM)

KPI CATEGORY	PO SCORE (%)
Excellent	80 – 100
Good	60 – 79
Satisfactory	50 - 59
Below Average	30 - 49
Weak	0 - 29

Comparison with ODL Semester (20204)

Teaching and learning in ODL were fully implemented in the semester of Sept 2020 - Jan 2021 (20204). Figure 5 depicts a comparison between students' grade attainment for semester 20194 and 20204. In general, students from semester 20204 performed better than semester 20194. A higher percentage of students from the semester 20204 achieved marks of 80% and above (grade A and A+), which is 87.3% compared to 80% for semester 20194. 51.5% of students from semester 20204 were able to obtain grade A and for semester 20194 only 41.8%. Moreover, a higher percentage of students in the semester 20194 obtained grade A (5.8%), grade A- (32.4%), grade B+ (14.7%), grade B (4.9%) and grade (B-) while only 4.1%, 31.7%,11.6%, 0.7%, and 0.4% of students in the semester 20204 for the same grade.

Figure 6 shows the comparison of students' grade attainment for psychomotor domain assessed on PT1 and PT2 for both semesters. As a whole, students from semester 20204 shows better performance. Accordingly, 20.9% of semester 20204 students achieved grade A+ and 50.75 percent earned grade A or higher compared to semester 20194. Based on PCM KPI category, a higher students' percentage from the semester 20204 achieved 'excellent' KPI category which is 71.6% and 28.4% of total students were in the 'good" category.

The results clearly indicate that students' performance for PT1 and PT2 is improving throughout the ODL. This trend shows that students who scored more than 80% were able to demonstrate good presentation skills during the practical test via synchronous session. The students are also more prepared and confident when performing the practical test without physically operating the laboratory equipment. However, due to a movement control constraint during MCO, students' psychomotor domain skill in operating the equipment cannot be clearly measured during ODL classes.

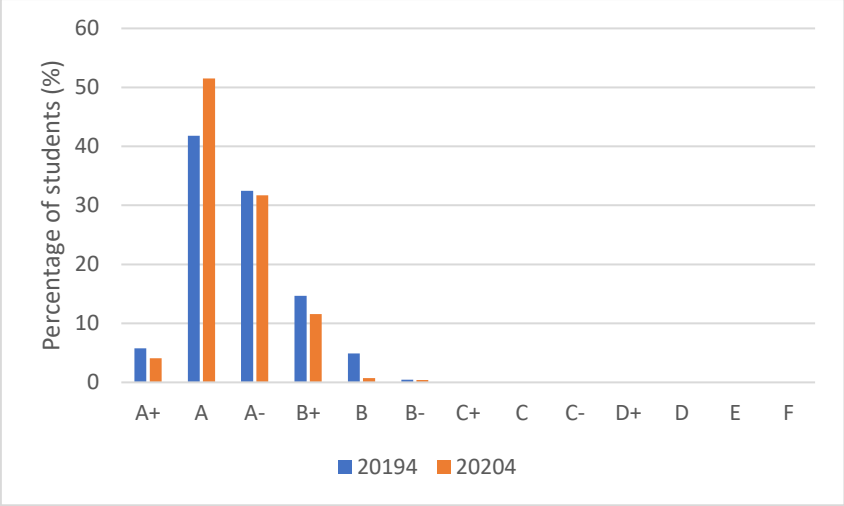

Figure 5: Comparison of Students' Grade Attainment for Semester 20194 and 20204

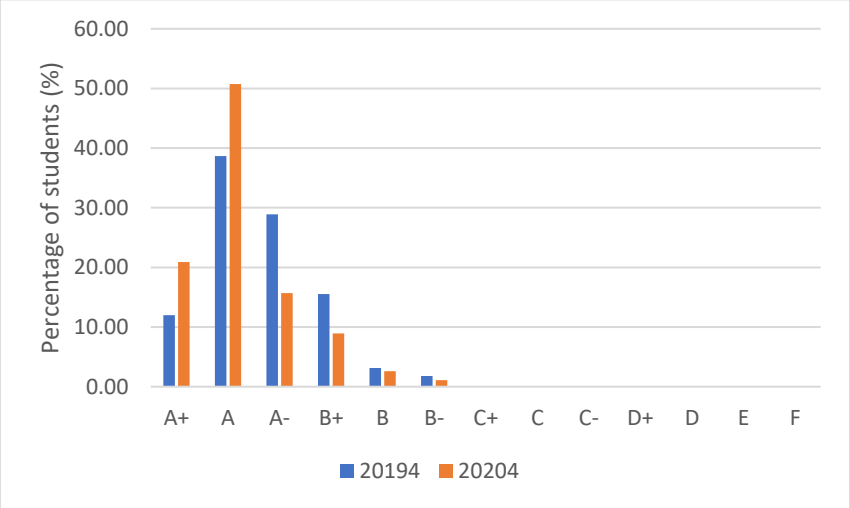

Figure 6: Comparison of Students' Grade Attainment for Psychomotor Domain (PT1 and PT2)

Conclusion and Recommendation

Practical skills are essential in engineering programmes. The two major challenges for academicians and universities during Covid-19 have been delivering and evaluating teaching and learning outcomes. In this study, a higher percentage of students' grade attainment for psychomotor domain shows 71.6% of the total students achieved 'excellent' KPI category and 28.4% of total students in the 'good' category while only 49.3% and 50.7% of total students from semester 20194 attained the same categories. These findings indicate that most of students were able to learn the relevant practical skills required for the course through ODL.

Through this study, several recommendations can be made to enhance online distance learning method. A review of the rubric for assessing PT1 and PT2 is necessary, particularly at psychomotor levels P4 and P5. In addition to that, lecturer need to be more creative on how to conduct practical test and improve their online teaching method. As an example, student should prepare physical props or animations for roleplay during practical tests to assess for psychomotor level P4 and P5. As another recommendation, IHL can provide funding or facilities for VR labs to facilitate lecturers and students during ODL sessions by using Virtual Reality (VR).

Nevertheless, face-to-face teaching and learning classes are more effective for learning and assessing psychomotor skills for this subject since it is first semester having ODL. However, change and better adjustment by resource person and lecturer should be credited for their effort in delivering the best practice of assessing psychomotor domain during ODL and future semester.

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