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Transformation of Delivery and Assessment for Laboratory Course During Covid-19 Pandemic: The Case Study of Soil Engineering Laboratory

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Abstract
Due to the spread of the COVID-19, many universities throughout the world are experiencing partial or complete disruptions to their academic programmes. As a result, more and more institutions are making the essential changes to their instruction in teaching and learning processes, including laboratory classes from face to face into a hybrid or online delivery format. Regardless of the actions done, lecturers must keep up their rigorous academic standards and offer a top-notch student as necessary for delivering the learning outcomes linked to courses especially laboratory courses that normally being conducted face to face in the laboratory or workshop to online or open distance learning (ODL). This transformation will present a challenge to academicians across the higher education sector, forcing them to switch from normal class delivery to online instruction and various laboratory delivery strategies. Students as a result will not receiving direct instruction from lecturers, and they have limited or no access at all to laboratory resources that necessary for delivering the learning outcomes linked to each programme courses. This paper reviews approaches taken by Faculty of Civil Engineering, UiTM and lecturers to deliver teaching and laboratory practices remotely, in consideration of the COVID-19 pandemic. This review is primarily focused on implementation on teaching delivery and laboratory assessments given to Civil Engineering Diploma Students in Soil Engineering Laboratory Course during COVID outbreaks. The findings of this study may be used to improve online engineering education during and after pandemics in other institutions or courses with a similar demographic.
Keywords: COVID-19, Open Distance Learning, Online Learning, Online Laboratory, Online Assessment, Soil Engineering Laboratory

Introduction

A novel coronavirus named severe acute respiratory syndrome (SARS-CoV-2) is the infectious disease known as coronavirus disease (COVID-19). It was originally discovered during an outbreak of respiratory sickness cases in Wuhan City, Hubei Province, China in 2019.

On 31st December 2019, it was initially reported to the World Health Organisation, WHO and was labelled as a worldwide health emergency on 30th January 2020. Then on 11th March 2020, WHO designated COVID-19 as a global pandemic. Nearly all nations and territories have been impacted by the global COVID-19 pandemic outbreak.

Most affected people with the virus will fall sick by having issues in respiratory conditions and experience mild to moderate symptoms and will normally recover without any special treatment. However, some people especially older people with underlying medical conditions will become seriously ill and require special medical attention. COVID-19 are known to infect humans and cause diseases including the common cold, Middle East respiratory syndrome (MERS), and severe acute respiratory syndrome (SARS), among others. When an infected person speaks, sneezes, sings, or coughs, the virus can be disseminated through their mouth or nose in tiny liquid droplets. It is crucial to infected people to use proper respiratory technique, such as coughing into a flexed elbow, wearing face masks, maintaining a physical distance, and avoiding large crowds and to stay at home until they feel better. In order to reduce and stop the spread of the disease, lockdown and homebound techniques have been implemented nationwide (Sintema, 2020)

The COVID-19 pandemic is primarily a health emergency thus these diseases effected to all sector and education is no exception. Education systems are facing a serious challenge from the COVID-19 pandemic. Many countries have made the wise decision to shut down their schools, colleges, and institutions in order to save lives and reduce human interaction. For the first time in the history of education, schools and higher institutions across the world including Malaysia were forced to make a sudden and unexpected academic switch to online or open distance learning (ODL) due to COVID – 19 pandemics. Many students all around the world are affected by the significant short-term disruption by taking an online class that give impact on students' social lives and learning as well as the productivity of the lecturers. Numerous evaluations have simply been cancelled and exams are shifting from face to face to online based, which is a big learning curve and source of concern for everyone. There are top concerns associated with this shift from in – person classes to distance learning activities especially those related to laboratory class delivery and assessment. During the earlier term of the closure of the universities, most lecturers may not be prepared to use virtual tools as the primary way of interacting. As the time goes by as soon as the following semester during the outbreak, the delivery method and assessment has been developed and improved by universities and lecturers including for the laboratory courses.

All areas of education have been impacted by remote learning or online instruction. This has had a significant impact on higher education, where students and lecturers now confront the burden of finishing their curricula and being ready for benchmark exams or final exams in a short amount of time. Benchmark tests, particularly in the secondary and higher education sectors, are, however, fraught with uncertainties. Exams cannot be taken online because they need to be closely monitored. Academic integrity and student assessment when students are not physically present in the classroom are among the difficulties educators' encounters. Take-home assignments allow for regular examination and evaluation, albeit they can occasionally compromise academic integrity (Kelum *et. al.*, 2020)

In engineering education, laboratory works, or practical works are essential to expose students in experiencing field works. Laboratory works will push students to self-thinking and students will learn by practicing the skills that cannot be learned theoretically. Laboratory activities is a very important component for engineering students. Their ability to perform and organize experiments without supervision are among the key skills that they need to acquire (Sharizan *et al.*, 2015). A graduate must have excellent soft skills apart from acquiring the knowledge on the subject matter. The students' psychomotor skills, commonly called manual or physical skill, are normally developed through laboratory setting (Roszilah *et al.*, 2012). Lecturers can use their creativity to develop the levels of psychomotor in the laboratory so that students can have the experience in handling machines and equipments.

Before the pandemic, most laboratory experiments in the classroom will end up with the lecturers giving specific information on conducting, analysis and reporting, making it easier for the lecturer while reducing the learning for the students. Leaving this step open-ended would help increasing confidence level in the students. The lecturer may explain the different report formats to the students, and they may be asked to write an initial draft of their report and then discuss their analysis with the lecturer, before finalizing their report. Even though this approach may work well for knowledge building through delivering content and oversight of some processes, it has limitations of developing one's practical laboratory skills. Therefore, it is critical to examine the methods used by universities to offer lab-based practical experiments to students, the way they were introduced via online delivery prior to COVID-19, and the strategies that must be used in the post-COVID-19 period.

The transition from traditional face-to-face delivery to online delivery is presented in this study focusing on laboratory courses prior to COVID-19. We also look at the problems and effects on assessment procedures put in place as a result of COVID-19. The main goal in this study is to discuss the implementation on laboratory practices delivery and assessment method before and during COVID-19 for Civil Engineering Diploma Students in Soil Laboratory Course. Engineering students need to graduate with excellent practical skills to become a great engineer. In order to fulfill the required criteria for accrediting engineering technology programs (ETAC, 2020) is by improving engineering education within a faculty. The teaching and learning methodology must incorporate a certain level of taxonomy on cognitive, psychomotor and affective domains. Engineering Technology is that part of the technological field that requires the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities (MQA, 2011). Hence, it is very important to make sure that the COVID-19 pandemic will not affect the outcome of each of the designated courses in the academic programme.

Laboratory Practice: Delivery and Assessment before Covid-19

The course of Soil Engineering Laboratory with the code of ECG263 in Diploma of Civil Engineering is chosen as a case study in this paper. This course allows the students to experience and carry out standard soil laboratory tests including physical properties and classification of soils, permeability, compressibility and shear strength of soils. At the end of this course, students would be able to demonstrate the investigation method related to soil engineering using standard tests and measurements. The course outcome is in line with the program outcome for Diploma in Civil Engineering those are able to conduct investigations of well define problems and function effectively as individual and team members in a technical team. The details of course outcome (CO) and program outcome (PO) for Soil Engineering Laboratory course are shown in Table 1.

Table 1
Course Outcomes and Program Outcomes

CO1	Demonstrate investigation method related to soil engineering using standard tests and measurements	PO4	Conduct investigations of well-defined problems; locate and search relevant codes and catalogues, conduct standard tests and measurements
CO2	Show appropriate techniques to soil engineering problem with an awareness of the limitations.		
CO3	Perform teamwork skills in task related to soil engineering.	PO9	Function effectively as an individual, and as a member in diverse technical teams.

Students would be able to show appropriate techniques in solving soil engineering problems with an awareness of the limitations. Apart from that, students are expected to be able to perform teamwork skills in task related to soil engineering. In this laboratory course, the experiments being conducted are grouped by level of openness based on the concept of Open-Ended Laboratory (OEL). The implementation of Open Ended Laboratory (OEL) teaching technique in Diploma Civil Engineering laboratory was changed from traditional concept to an OEL concept since 2013 to fulfil requirement from Board of Engineers (BEM)(EAC, 2012) and ETAC, 2020. There are 4 level of openness those are Level 0 until Level 3 as shown in Table 2. The levels of openness are mostly categorized as problems, ways/means and answers (Kilinc, 2005). Previous method of teaching laboratory courses is basically in the form of fully guided assignment which is described as traditional method. However, this method is now no longer adequate within the context of outcome-based learning environments (Norliza *et al*., 2011). Thus, the need for an open-ended laboratory is emphasized in enhancing independent learning cultures and inculcate creativity and innovativeness of students. The percentage of level of openness are distributed by semester. For the lower semester course, lower percentage of openness will be assigned and will increased for the higher semester course. For soil engineering laboratory which is the 4^{th} semester course, 50% of openness will be implemented for level 0 and level 1.

Table 2
Level of Openness

Levels of laboratory openness			
Level	**Problem**	**Ways & Means**	**Answers**
0	Given	Given	Given
1	Given	Given	Open
2	Given	Open	Open
2	Open	Open	Open

The assessment for this course is focusing on psychomotor domain which is 90% from the overall continuous assessment. The psychomotor skills consist of two numbers of practical tests and lab activities with 50% and 40% of assessment marks contribution respectively. Whereas lab observations contribute 10% marks focusing on the affective domain. The summary of distribution marks for this code is tabulated in Table 3.

Table 3
Distribution Marks for ECG263 Assessments

Continuous assessments	Taxonomy Domain	Marks
Practical tests (2 Tests - 25% each)	Psychomotor	50%
Lab activities	Psychomotor	40%
Lab observations	Affective	10%
	Total	**100%**

Based on the syllabus of Soil Engineering Laboratory, two numbers of practical test are required for assessment to address psychomotor domain of the students. Before pandemic, practical tests are implemented face to face and students are individually assessed. This assessment is to measure the ability of the students to conduct soil engineering testing using standard equipment and measurements.

For the laboratory activities, the students will be assessed to address psychomotor domain individually from the start until the end of the lab test. Each student will be assessed one time on each level of openness and topics to be tested will be given randomly to the student. Students will be assessed in term of the following:

i) Identification the purpose of the experiment or given scenario
ii) Recognition the machine/tools or apparatus needed for the activities
iii) Decision the number of samples to be used or collected, sample type, location and preservation (if required) based on the given experiment condition
iv) Preparation of sample and setup the equipment
v) Independently and confidently conduct the experiment. Carefully follow each of the steps
vi) Perform experiment safely and aware of priorities in the laboratory
vii) Record relevant experimental data in orderly manner
viii) Ability to adapt the obtained result and understanding of finding

For laboratory observation, affective domain rubric is referred to whereby the students are assessed in a group in term of attendance punctuality, participation, and cooperation to achieve group goals, safety, time management in completing the experiment and submitting the report, organization of task and lab work as well as understanding the outcomes of lab activities.

Laboratory Practice: Delivery and Assessment during Covid-19

In engineering education, laboratory works, or practical works are essential to expose students in experiencing field works. Laboratory works will push students to self-thinking and students will learn by practicing the skills that cannot be learned theoretically. Laboratory work is a very important component for engineering students. The ability to perform and organize experiments without supervision are among the key skills that they need to acquire

(Sharizan *et al.*, 2015). A graduate must have excellent soft skills apart from acquiring the knowledge on the subject matter.

The students' psychomotor skills, commonly called manual or physical skill, are normally developed through laboratory setting (Roszilah *et al.*, 2012). Lecturers can use their creativity to develop the levels of psychomotor in laboratory works so that students can experience in handling machines and equipment's. Engineering students need to graduate with excellent practical skills to become great engineers. In order to fulfil one of the required criteria for accrediting engineering programs is improving engineering education within a faculty (ETAC, 2020). The teaching and learning methodology must incorporate a high level of taxonomy on cognitive, psychomotor, and affective domains (MQA, 2009).

Following the recommendation of public health professionals to preserve social distance during the COVID-19 pandemic, universities and colleges were swiftly closed and educational institutions had to quickly adopted e-learning under Online Distance Learning (ODL) since March 2020. Distance learning has limitations especially when it comes to one's practical laboratory abilities. For instance, if working in a laboratory setting, one would frequently come across numerous sorts of laboratory equipment. Operating in a distant learning mode will denies students valuable hands-on experience to such facilities and the opportunity to really understand the process of handling and conducting the laboratory experiments. In order to achieve learning outcomes while maintaining a high-quality educational experience, the faculty had to review how the teaching & learning processes can be conducted via online including the delivery and assessment method for laboratory courses.

A programme for engineering education must include laboratories because it is the most important part of an engineering education program. Laboratories are able to link the applying concepts learnt in class to the real-world situations and giving a different viewpoint to aid the students' learning. As for Civil Engineering Diploma Programme UiTM, one of the programme educational objective is to produce civil engineering technicians who is competent is applying knowledge, practical skills in civil engineering and pursuing further knowledge for higher qualification. Many people are in favor of using interactive laboratories. The use of hands-on laboratories is supported by many different learning theories, such as inquiry-based learning, constructivism, active learning, as well as cooperative learning if the lab is completed in groups (Sean, 2021).

Soil Engineering Laboratory is a 4th semester laboratory code in University Technology MARA for Diploma in Civil Engineering Programme. The focused of this course is to allow the students to experience and carry out standard soil laboratory tests including physical properties and classification of soils, permeability, compressibility, and shear strength of soils. This course would typically provide students with hands-on experience using tools such as sieving, Atterberg limit tools, triaxial, shear box and many others. Therefore, it was a challenge for lecturers and instructors to change or replace the in-person laboratory components of this course during the COVID-19 outbreak.

During the pandemic, two methods of delivery approached has been selected to deliver the content of this syllabus which are non-interactive laboratory and home laboratories. For non-interactive laboratory, lecturers or instructors will provide the related video demonstrations and slides that corresponds to each laboratory sessions in which the students will be exposed to the knowledge on how the psychomotor action of conducting the laboratory experiments. Video-based activities provide a step-by-step overview of a real lab procedures so that students can see and visualise the whole experimental process and its environment through a video. The output data from actual experiments will also be provided to the student for analysis and discussion of the findings. Students will receive guidance from their lecturers through a various online medium such as live meeting, recorded video, online forum discussion and any other relevant approach within this period.

Non-interactive laboratories method has been commonly adapted during the pandemic because it is very easy to adapt an existing in person laboratory to a remote learning course by making a video demonstration using the existing equipment. However, this approach will not give the hands on experienced to students on how to conduct the real experiments. As a result, the students will become passive learner, and this will lead to decreased of their enthusiasm in the learning activities.

Home laboratories will either give students access to actual hardware or ask them to buy particular hardware, which they then use to finish the lab in their own homes. The advantages of home laboratories are that they are entirely hands-on, just like conventional in-person laboratories. However, financial, logistical, and practical considerations can restrict the potential for home laboratories. For instance, setting up home laboratories with expensive or even dangerous equipment might not be possible (Sean, 2021).

Home laboratories for soil engineering laboratory was designed and developed by team lecturers of Soil Engineering Laboratory course which could be completed by students in their own homes. In order to overcome the common practical limitations of the home laboratories approach, the utilized resources had to be affordable and readily available. The laboratory was developed to utilize any relevant equipment of resources available around the student's vicinity. The experiment also required the use of commonly available materials and equipment such as soil, tray, balance, bottle, measuring tape, excavating tools like shovel etc. The effectiveness of this method for integrating a hands-on laboratory experience in a distance learning environment was observed by considering the lessons shown in the student's mini project that will contribute 40% of their carry marks in this course.

Assessment is the measurement of learning that comprises measuring knowledge, skills, and abilities of a student. For Soil Engineering Course, the method of the assessment had changed to suit the online distance learning environment and all the assessment need to be conducted online. For this course, there are three types of assessment which are practical test, laboratory observations and laboratory activities. During ODL semester, the laboratory observations and laboratory activities were changed to mini project and laboratory reports respectively. Even though the type of the assessments were changed, the taxonomy domain skill measured from the students are remain the same which 90% physcomotor skills and 10% affective skills being measured. The changes of type and method of delivery for assessment during COVID-19 semester is tabulated in Table 4.

Table 4
Course Assessment Plan For ODL

	CLO	PO/PLO	Taxonomy Domain	Teaching & Learning Activity	Assessment Weightage (%)
1	Demonstrate investigation method related to soil engineering using standard tests and measurement	PO4/PLO2	Psychomotor	Open Distance learning	Practical test 50%
2	Display appropriate techniques of soil laboratory testing for soil engineering problem with an awareness of the limitations	PO4/PLO2	Psychomotor	Open Distance learning	Mini Project 40%
3	Perform teamwork skills in task related to soil engineering	PO9/PLO5	Affective	Open Distance learning	Lab Report 10%

Practical Test

Practical test will be conducted 2 times during the semester. A few sets of test questions or different arrangement of test questions will be prepared. Students will be given names of laboratory testing that will be asked in practical tests earlier using Microsoft/Google Form/ or any other suitable platform in order to prepare or improvise the tools for laboratory testing. During live interview session, 1 set of questions will be picked randomly. Student needs to detail out the procedures and demonstrate the laboratory testing in the form of live video presentation using simple model from whatever resources or item available around them that they have prepared earlier. The detail marks given for practical test is tabulated in Table 5.

Table 5
Practical Test

Practical Test No.	CLO	PO/PLO	% Assessment Marks	Duration (mins)
Test 1	CO1	PO4/PLO2	25	20
Test 2	CO1	PO4/PLO2	25	20

Mini Project

One mini project will be given to the students using Microsoft Teams/Whatsapp group/Google drive to challenges and encourage them to think beyond the boundaries to develop the skills, behaviors, and confidence in order to fulfill the project requirements. The project requires the students to develop their psychomotor skills and they will submit the project individually in the form of report/poster/video presentation.

The task will emphasize on students' ability to discover, and innovatively conduct certain soil engineering tests within the vicinity of their area. Students are advised to collect soil samples and conduct soil experiment that can be associated to soil mechanics fundamental concepts and describe the soil in terms of the water/ moisture content, particle density, particle size grading and texture, field density and permeability. Due to a constraint of utilizing the standard equipment for soil engineering identification and exploration, students can creatively utilize and improvise any tools and technique to achieve the objectives of the experiments.

The detail of the procedures of each of the home laboratory has been detailed out in the class. For example, as of moisture content determination test, instead of using laboratory oven, students need to conduct the experiment using air drying method. Students need to extract the soil sample from the sampling location and divided the sample into 3 parts and then spread the soil evenly in the metal tray. The soil needs to be exposed for the air-drying process for the duration of one whole day (overnight) or depend on whether condition until the soil sample become completely dry. The moisture content of the soil sample can be calculated by measuring the weight of the soil sample before and after the drying process.

For particle density test, students need to prepare three 500ml to 1000ml glass jar or plastic bottles. This method is an improvisation of the particle density testing via the pycnometer bottle method that usually being conducted on site. For dry sieving test, students need to prepare four to five different sizes of nets ranging from size 1mm to 30cm of sizes. They need to fabricate the frame of the sieve by using wooden frame and fitted the nets to the wooden frame by using staple gun or etc. The sieving test can be conducted by using this DIY sieve.

For preparation of DIY falling head testing, students need to find 3 plastic bottles (3 sets of testing) and need to drill a few small holes at the bottom of the bottle. Then, cut off the top part of the bottle, fill the soil into the bottle and compact it with wooden peg. Four level points then marked above the soil and water in the bottle were filled up to the top and leave it for a while until all the soil is fully saturated and top up the water till it reaches the mark. Then, students can start observing the time of water to reach the marking point. This method is an improvisation of the falling head testing method.

For field density test, students need to prepare 3 steel containers of similar size. They need to follow the steps and concept of core cutter method. Students can use a rubber mallet for hammering the container into the ground. Then, the container with soil will be dug out and observation and measurement can be made. This method is an improvisation of the field density testing via the core cutter method. Calculation involving the field density of soil and the dry density of soil. The details marks distribution of Mini Project is tabulated in Table 6 below.

Table 6
Mini Project

Mini Project	CLO	PO/PLO	% Assessment Marks	Duration (weeks)
- Soil testing project - Individual video presentations /report /poster via any relevant method	CO2	PO4/PLO2	40	6

Laboratory Report

During ODL semester, assessment for 10% laboratory activities has been changed to laboratory report assignment. This course outcome is to assess the teamwork skill among students in groups related to the soil engineering activities. Since the direct observation in the laboratory cannot be done during that semester, the teamwork skill will be assessed in the form of their contribution as a team member in producing the laboratory reports. The detail of the laboratory reports is tabulated in Table 7 below.

Table 7
Laboratory report

Laboratory	CLO	PO/PLO	% Assessment Marks	Duration (days)
Lab level 0	CO3	PO9/PLO5	5	7
Lab level 1	CO3	PO9/PLO5	5	7

Discussion

Table 8 below shows the summary of outcomes and assessments for Soil Engineering Laboratory (ECG263) course. The marks distribution of the assessment according to program and course outcomes remains the same before and during the Covid-19 semester. However, the method of delivery and assessments was improvised to suit online distance learning during Covid-19 semester but still meet the requirements and be in line with the course and program outcomes. The effectiveness of OEL implementation during pandemic can be proven, where it can provide opportunities for lecturers to guide and open up space for students to better understand the concept of laboratory testings in a more creative and innovative way. It gave the same understanding to students even though the laboratory session was conducted or demonstrated using online medium. All of this was being observed by their successfully submitted mini project and laboratory report, together with their successfully practical tests session during COVID-19 semester.

Table 8
Outcomes and Assessment for ECG263

CLO	**PO/PLO**	**Continuous assessments before Covid-19**	**Continuous assessments during Covid-19**	**Marks**
CLO1	PO4/PLO2	Practical tests (Face to face)	Practical tests (Online)	50%
CLO2		Lab Observations	Mini Project (Home test)	40%
CLO3	PO9/PLO5	Lab activities	Laboratory Report	10%
Total				**100%**

The first course outcome is to demonstrate the investigation method related to soil engineering using standard tests and measurements. Students were assessed through a practical test session regarding their understanding of using standard equipment in the laboratory. Although the method of delivery before and during Covid-19 semester were different, students managed to gain optimal understanding of the syllabus content. It is because virtual learning was conducted with various method, namely recorded videos, and live sessions where students can be virtually exposed to the actual equipment and the procedures of the laboratory experiments step by step. After that, students can increase their understanding of each lab procedure and concept by doing a home test for the need of mini project assessment. A home test is a hands-on test procedure improvising the laboratory testing procedure in the vicinity of the students. This will also indirectly fulfill the second-course outcome, where the students can display appropriate techniques of soil laboratory testing for soil engineering problems with an awareness of the limitations. Other than that, this will enable students to conduct investigations of well-defined problems; locate and search relevant codes and catalogues and conduct standard tests and measurements during pandemic.

For the third-course outcome which is to perform teamwork skills in tasks related to soil engineering was fulfill by using the student's laboratory report instead of laboratory activities before pandemic. The outcome of the program which needs to see students function effectively as an individual, and as a member of diverse technical teams can be translated by the generated output of laboratory reports for each test conducted by group.

The overall approach taken by faculty was a success and can be proven by students' examination results before and during pandemic. Table 9 below shows the average achievement of students by their PO scores starting from the year 2019 until year 2021. The passing score for each course outcomes is 50%. It means students should pass the minimum requirement of 50% of total mark for each program's outcomes. From the results, it shows that there is not much different of the students score from the year 2019 until 2020.

Table 9
Student's Score by PO attainment

Semester	PO Score (%)	
	PO4	**PO9**
2019(2)	78	76
2019(4)	80	78
2020(2)	85	76
2020(4)	73	79
2021(2)	74	75
2021(4)	74	70
Passing PO (50%)	**50**	**50**

Figure 1 shows the chart of the average score of PO attainment. In the year 2020 and 2021, there is slightly decrease of the scores of PO4 and PO9. However, there is no big issues since the gap of the marks are small and all the scores were above 70%.

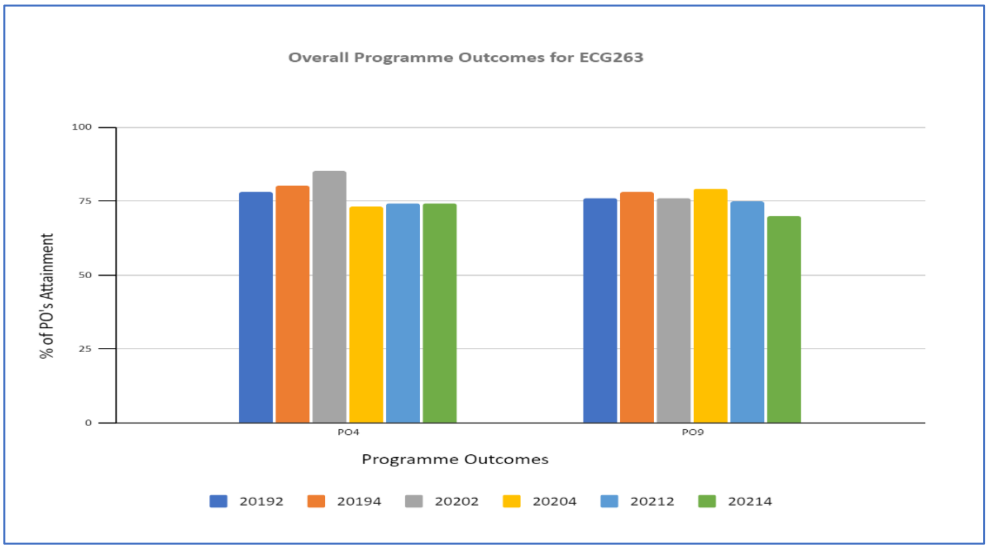

Figure 1: Chart of Average Score of PO Attainment for ECG263 by Semester

Conclusion

The transformation of normal delivery of teaching and assessment with online based learning methods of laboratory course for the case study of Soil Engineering Laboratory have been identified and discussed. For this fourth-semester soil engineering laboratory, using laboratories that students could improvised and conduct in their own homes turned out to be a beneficial strategy. This strategy was made possible by using materials or resources in the vicinity of the students that are affordable and widely accessible. The reaction of the home laboratory by students was extremely positive and the student's exceptional level of learning was shown in the form of their submitted assignment through mini project and laboratory report. The students' ability to perform well in the practical tests session also can be an indicator that the method of delivery and assessment during the pandemic was a success for this course. This strategy might be advantageous in other online engineering classes especially for laboratory courses during and post pandemic.

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