INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN PROGRESSIVE EDUCATION & DEVELOPMENT

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ISSN: 2226-6348

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To Link this Article: http://dx.doi.org/10.6007/IJARPED/v11-i4/15423 DOI:10.6007/IJARPED/v11-i4/15423

Received: *16 September 2022,* ***Revised:*** *22 October 2022,* ***Accepted:*** *11 November 2022*

Published Online: 20 *November 2022*

In-Text Citation: (Latiff et al., 2022)

To Cite this Article: Latiff, Z. I. A., Sidik, N., Zin, N. A. M., & Zainuddin, A. (2022). Implementation of Electrical Engineering Laboratory Course for Diploma Studies in Electrical Engineering during COVID-19 Pandemic Phase. *International Journal of Academic Research in Progressive Education and Development*, *11*(4), 40–53.

Vol. 11(4) 2022, Pg. 40 - 53

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Implementation of Electrical Engineering Laboratory Course for Diploma Studies in Electrical Engineering during COVID-19 Pandemic Phase

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Abstract
The rapid spread of a new coronavirus (COVID-19) has interrupted lectures and classes worldwide (COVID-19). Many academic institutions are moving toward online or blended course delivery, including laboratory course. This paper presents Electrical Engineering Laboratory course implementation during the COVID-19, highlighting the applied methodology and student's practical skill performance. The Electrical Engineering Laboratory course for Part 3 students of two diploma studies at Universiti Teknologi MARA (Pasir Gudang Campus) was implemented using an extended methodology. The methodology includes analysing the structure of Electrical Engineering Laboratory Course, selecting a relevant teaching method and delivering for each experiment, and using OBE-ANAS to measure the Course Outcome (CO) and Programme Outcome (PO). In the CO-PO analysis, a few important elements of Electrical Engineering Laboratory course are measured, but the most important element, which indicates practical skills in using modern engineering tools, has moderately surpassed the performance level set for this particular CO-PO Mapping despite the blended mode of delivery. It is may be due to the wise selection of experiment delivery mechanism. However, future study may compare the complete face-to-face delivery of the electrical engineering laboratory course with blended mode delivery to examine the effect of delivery mode on the laboratory course's execution.
Keywords: Electrical Engineering Laboratory Course, COVID-19, Course Outcome, Programme Outcome, Online Delivery

Introduction

In March of 2020, Malaysia issued a declaration of a state of emergency in an effort to restrict the further dissemination of the COVID-19 virus. As a result, all areas of the economy that were not considered essential were either completely shut down or placed under limitations whose primary purpose was to further isolate the people. During the COVID-19 pandemic, universities promptly requested that classes be cancelled in order to comply with the advice of public health experts to keep individuals apart (Murphy, 2020). Because of this, educational institutions all around the world started offering classes online, using the distance learning method (Morgan, 2020).

The Electrical Engineering Education programme emphasize how important it is to develop both the theoretical (content) and the practical (processes) aspects of the field. Activities that educate students how to perform experiments, analyse observations, conclude findings, and experimental practises are given particular focus throughout the development of the practical components. Although it is beneficial for broadening one's knowledge base by sharing material and monitoring selected processes, this type of education is not ideal for developing one's competency in the laboratory environment. For example, in a laboratory, one may utilise a wide range of high-priced instruments and machines that are also quite technologically sophisticated. Students who choose to pursue their education through a mode of instruction known as distance learning, on the other hand, miss out on the opportunities to obtain the kind of hands-on experience and sensitivity to subtleties that come with being fully engaged in the context in which they are studying. Therefore, it is an utmost importance for educational institutions to determine how a laboratory course should be presented to students through the medium of online delivery, as well as what strategies need to be implemented in the post-covid-19 era in order to accomplish learning outcomes without sacrificing the quality of the academic experience that students should have received.

However, notwithstanding the challenges brought on by the absence of the traditional laboratory class format, the institution must still adhere to the requirement stipulated by the accreditation. When it comes to maintaining an institution's credibility and standing in the world of higher education, accreditation is essential. That is crucial for a university whose students and alumni are all aiming for high levels of accomplishment in their chosen fields. It's also for the sake of maintaining Malaysia's engineering program's enviable reputation for excellence. Each institution is responsible for determining whether or not their own programme meets the required criteria of accreditation (Program Educational Objective (PEO), Programme Outcome (PO), Course Outcome (CO), Assessment, Students, Facilities, Program Criteria, etc.). It is required by the Engineering and Technology Accreditation Commission (ETAC) that there be strong proof of students' achievement of learning outcomes (Premalatha, 2019). All steps taken by the university to create, implement, analyse, and evaluate the programme that should be documented. Because of its emphasis on results, particularly on student successes, the Outcome Based Education (OBE) system has been formed as an approach in this curriculum.

Careful assessment of the OBE paradigm's implementation and its impact on the educational system as a whole, and on students and instructors in particular, is now required to meet accreditation standards. As stated in the mentioned research paper, "outcomes-based education" is described as "clearly focusing and structuring everything in an educational system on what is needed for all students to be able to achieve effectively at the end of their learning experiences" (Spady, 1986), In contrast to the conventional system, OBE provides an alternative approach to converging outputs by placing more emphasis on inputs and processes (Zeynal et al., 2017). The results provide an assessment of the program's efficacy based on the benchmark in educational practise. Since the execution of the laboratory course has been affected by the COVID-19 pandemic, it is essential that the laboratory course be designed in line with the aligned CO and PO to maintain the course performance.

Therefore, the objective of this study is to examine the methodology that was used to carry out the implementation of the Electrical Engineering Laboratory course during the pandemic phase of the COVID-19 virus. The relevant results were analysed with the OBE-ANAS measurement tool, which determines the effectiveness of an implementation by assessing the CO and PO performances. The research was conducted on students who were enrolled in the third semester of both the Diploma in Electrical Engineering (Electronics) and the Diploma in Electrical Engineering programmes (Power) at Universiti Teknologi MARA (Pasir Gudang Campus). This study is carried out during the semester of the year 2021.

Methodology

This section will provide a detailed description of the structure of the Electrical Engineering Laboratory course. This is performed so that the various different hands-on components that are included in the laboratory can be identified. This section will go into details on the approach that was employed when delivering the laboratory course both in a conventional laboratory setting and in an online platform. This section also includes a description of the measurement tool that was applied to the process of assessing the performance of both the CO and the PO.

1. **The structure of Electrical Engineering Laboratory course**

Electrical Engineering Laboratory course is a compulsory laboratory course for all Semester 3 students in two Diploma studies at Universiti Teknologi MARA (Pasir Gudang Campus), which are Diploma in Electrical Engineering (Electronic) and Diploma in Electrical Engineering (Power). These students are the very first cohort to sign up for Diploma studies within the framework of the ETAC curriculum. Due to the fact that the ETAC curriculum focuses a larger emphasis on technical capabilities, significant consideration must be given to the evaluation of psychomotor level in laboratory courses. One of the goals that students are required to accomplish at the end of the Electrical Engineering Laboratory course is to display competent practical abilities in the context of carrying out experiments utilizing the use of modern engineering tools. As a result, the major objective of this course is to acquaint the student with the cutting-edge engineering tools that are now in use. The structure of the Electrical Engineering Laboratory course is laid out in table 1. From the table, it can be observed that this laboratory course consists of 7 Experiments and 1 Mini-Project.

Table 1
The structure of Electrical Engineering Laboratory Course

No	Experiment	Name of Experiment
1	Exp 1	Introduction to Embedded System
2	Exp 2	Introduction to Numerical Computing
3	Exp 3	Introduction to Numerical Computing
4	Exp 4	CST for Beginners
5	Exp 5	Cloud & Drive
6	Exp 6	Introduction to Excel
7	Exp 7	Introduction to Autocad
8	N/A	Mini Project

Selection of instructional approach and mode of delivery for every experiment

Since this laboratory class encompassed such a wide variety of distinct topics, the requirements for every experiment were highly specialised. Every experiment has to have a detailed strategy laid out for it in order to ensure that the expected objectives may be achieved even when the experiments are being conducted in a virtual setting. If students spend an excessive amount of time attempting to find out how to utilise the virtual tools, they will not have time to have a grip on the concept behind the laboratory or the fundamental concepts of electrical engineering. Therefore, it is vital to consider that while estimating the amount of time needed for each mode of delivery. According to the findings of Gao et al (2017), one of the most important steps to take in order to guarantee consistent growth in the classroom is to provide comprehensive instructions during the planning, execution, and assessment stages. The concepts of segmentation and adaptation (Gunathilaka, 2018) mandate that either a live virtual laboratory activity or recorded video instructions are necessary in this situation. In this particular scenario, either a synchronous introduction to a virtual laboratory or asynchronous recorded video instructions are extremely necessary. The lecturers will be able to show how to carry out the experiments in a virtual environment with the assistance of these technologies. Therefore, in order to attain the desired level of teaching quality, the pedagogical strategies that should be taken into consideration are as follows:

i) Using the e-learning platform to disseminate material such as recorded video classes and downloaded pdf files;
ii) Video conferencing for live presentations, interactive screen sharing (between lecturer and student), and other types of real time, synchronous communication;
iii) the use of asynchronous methods of communication, such as email or a group messaging service such as WhatsApp or Telegram.

OBE ANAS as the measurement method for PO Attainment

The adoption of OBE necessitated a change to the evaluation method, and lecturers were instructed to provide students with guidance that was directly proportionate to how well they were doing. The Program faculty should give evidence in the form of quizzes, examinations, laboratory work evaluation, case studies, mini-projects, and industrial training in order to facilitate a continuous quality improvement process (Sudheer et al., 2017), (Rahman et al., 2016). The evidence for the evaluations was then evaluated by faculty through reviews and observations of student work that was pertinent to the needs of the programme. It is important to remember that a program's approach for continually improving students' outcomes should be well-structured in order to permit continuous development pertinent to the programme level of students' learning in order to perform an effective assessment of the process (Najadat et al., 2016). The evaluations have been designated as a crucial part of the OBE process. This laboratory course's CO and PO can be used to track students' development as they work toward OBE achievement. In order to carry out the OBE, the suggested measuring instrument is employed to access the PO, which is connected to CO and assessment measurements. In this laboratory class, we utilise the OBE-ANAS tool to assess both PO and CO development. The graphical user interface (GUI) for the OBE-ANAS tool was developed using C#, an object-oriented programming language. Table 2 displays the course's CO and PO lists while the mapping of COs and POs in this course tabulated in table 3.

Table 2
List of CO and PO of Electrical Engineering Laboratory Course

Course Outcome (CO)	Description
CO1	Display good practical skills in conducting the experiments/project using modern engineering tools during laboratory sessions
CO2	Discuss the impact on society and the environment in finding the solution of well-defined engineering problems.
CO3	Work effectively as an individual and a team member while conducting the experiments in a group
CO4	Demonstrate verbal and written communication skills in reporting the conducted experiments and project.

Program Outcome (PO)	Description
PLO5	Apply appropriate techniques, resources, and modern engineering and IT tools to well-defines engineering problems, with an awareness of the limitations.
PLO7	Understand and evaluate the sustainability and impact of engineering technician work in the solution of well-defined engineering problems in societal and environmental contexts
PLO9	Function effectively as an individual, and as a member in diverse technical teams
PLO10	Communicate effectively on well-defined engineering activities with the engineering community and with society at large, by being able to comprehend the work of others, document their own work, and give and receive clear instructions

Table 3
CLO and PLO Mapping of Electrical Engineering Laboratory Course

	PO5	PO7	PO9	PO10
CO1	✓			
CO2		✓		
CO3			✓	
CO4				✓

Results and Discussion

1) Implementation of Laboratory Practices for both face-to-face and online mode

Implementation of a Laboratory Course during global pandemic COVID-19 phase requires considering the fact that we are obligated to adhere to a number of regulations imposed by the Ministry of Health (MOH). The implementation procedure for the Electrical Engineering Laboratory course that is offered at the Pasir Gudang Campus of Universiti Teknologi MARA also has to be revised because of these constraints. Only students who have special needs are permitted to return to faculty at this time in order to prevent an excessive number of students from returning. However, the students in special needs are only permitted to return to the faculty for a period of five weeks. Alternately, the first group of students with special needs will be required to return home and continue their education using the online mode while the second group of students with special needs will arrive. Students who are considered to have special needs are those who are required to enrol in a laboratory course. There is a total of fourteen weeks in a whole academic semester. Due to the fact that only 5 weeks are allocated for face-to-face delivery, all experiments for this laboratory course need to be studied carefully in order to determine which experiments need to be executed in face-to-face mode, and the rest experiments need to be performed in online setting. According to the information shown in table 1, there are a total of seven experiments that need to be carried out by the students. Therefore, in order to identify the effective laboratory implementation, the contents of the laboratory manual especially on the objective of the experiments need to be evaluated in the properly. From there, the software that is going to be utilised for that specific experiment can be selected as the most appropriate option. As a consequence of this, Table 4 contains a list of the experiments, as well as the software associated with them, and the mode of lecture.

Table 4
List of Software and Lecture mode for every experiment conducted in Electrical Engineering Laboratory Course

Experiment	Name of Experiment	Software	Mode of Lecture
Exp 1	Introduction to Embedded System	Arduino kit / Tinkercad	Face – to – face / Online
Exp 2	Fundamental to Hardware Description Language	Altera	Face – to – face / Online
Exp 3	Introduction to Numerical Computing	Phyton	Online
Exp 4	CST for Beginners	CST Software	Face – to – face
Exp 5	Cloud & Drive	Google Drive	Online
Exp 6	Introduction to Excel	Microsoft Excel	Online
Exp 7	Introduction to Autocad	Autocad	Face – to - face
	Mini Project	One of software learnt in this laboratory course	Online

In Experiment 1, there are two different types of lectures, which are known as the face-to-face mode and the online mode, as can be seen in Table 4. Due to the fact that this experiment requires the student to be able to develop coding and hardware using Arduino kit, it was initially planned that experiment 1 would be carried out in a face-to-face setting. Because there have been certain occasions in which students have not been able to attend the course owing to COVID-19, it is necessary to conduct this experiment using an online medium. Alternately, students who tested positive for COVID-19 are need to use simulation software in order to perform out experiment 1. Tinkercad is a web-based tool that may be used for three-dimensional design, electronics design, and programming. Tinkercad is an application that provides a number of capabilities, one of which is the simulation of electronic components and microcontrollers within an Arduino environment. Even if the experiment is carried out in an online setting, the objective of experiment 1 can still be accomplished without any significant reduction in the level of understanding exhibited by the students.
Experiment 2 is an experimentation related to Hardware Description Language (HDL). HDL stands for "hardware description language," and it is a language that can describe the hardware of digital systems in textual form. The Student Learning Time (SLT) for Experiment 2 is considerably longer than the other experiments, which is 8 hours. As a result, the time spent in the laboratory doing this specific experiment will be split between two sessions, each of which will last for a total of four hours. The first session of this experiment will last for four hours and will be done in a face-to-face setting with the students. The following session will last for four hours and will be completed online. The student will make use of the chance presented to them during the first four hours of the session in order to become acquainted with the functions of the software. This will ensure that the student will have no issues carrying out the experiment 2 when they return home later. The programme known as Altera web-edition was the tool utilised for this Experiment 2. Since this application does not require for a large capacity of storage and simple to be set up, Experiment 2 can be carried out using the online mode. Experiment 3, experiment 5 and experiment 6 are selected to be performed in online mode since these experiments are less complicated and easy to be used software which are web-based phyton, google drive and Microsoft Excel respectively. Experiments 4 and 7 are regarded to be among the most crucial experiments, hence it is imperative that they be carried out under the lecturer's close supervision and guidance. Because of this factor, it

is imperative that these two tests be carried out in a face-to-face setting. CST software and Autocad are software applications utilised in these two experiments. Since this two software were never utilised by students, teachers were responsible for guiding students through any difficulties they encountered while trying to use the software. In addition, this software requires relatively high-capacity storage and special license. These are all fair arguments for why it is important that these experiments be carried out in a face-to-face setting. Students were instructed to use the remote desktop application in the event that there were any students affected by COVID-19 who were unable to attend the physical laboratory session. Any Desk is a remote desktop software that is used as the mechanism that enables students to access any computer in the computer laboratory of the faculty. Once a student is logged into any computer, they are able to utilise the software that is installed on that specific computer. Another benefit of utilising this "anydesk" application is that it allows the lecturer to monitor the students while they are performing the experiments by viewing the computer that the student is remote-desking from. The purpose of the experiment can still be accomplished by the student even when the student is not present in person, and this will not compromise the student's level of understanding in any way.

Students were given the task of developing a mini project that incorporated some aspect of sustainability as part of their assignment for the mini project implementation. The students will have a total of five weeks to finish the small project that has been assigned to them. The mini project requires the students to use at least one of the software skills that they have gained from Experiment 1 through Experiment 7, and they must do it by placing the skill into practise. They are required to apply the software skills that they have acquired in order to solve an engineering challenge and provide a solution that incorporates a component of sustainability. The online mode will be used for the delivery of the mini project, and the students will be required to present their projects using the online method during the final week of the learning week.

2) **The usage of Microsoft teams as online delivery platform and WhatsApp as group Messaging**

Microsoft Teams serves as the platform for carrying out laboratory sessions and exchanging laboratory materials in the context of delivering laboratories courses in an online setting. According to data in table 4, only some experiments necessitate online execution. One Microsoft Teams group, specifically for this Laboratory course, is formed, and all enrolled students and participating faculty members are expected to join this group. As can be seen in Figure 1, a Microsoft Teams group has been set up for this lab class, and inside that group, numerous channels for Experiments 1 through 7 have been established. When it is time for the online lab session, students will tune in to the appropriate channel to participate in the lecturer's session. We use Microsoft Teams not just to have class discussions and distribute assignments, but also to collect and distribute student lab reports and relevant supplementary materials. Given that Microsoft groups may be synced with the OneNotes programme, grading lab reports is as simple as opening the submitted report in OneNotes and providing the appropriate marks. Since Microsoft Teams syncs with One Drive, student's completed assignments can be accessible from there as well. One Drive can be used to properly document all necessary laboratory documents, including the Laboratory Course Outline, Laboratory Manual, and Student Laboratory Report. It is crucial to keep detailed records of all aspects of a course, since a periodical quality audit will be conducted to check whether the course is being carried out according to the standards set by accrediting bodies or not.

While Microsoft Teams' feature is useful, WhatsApp groups have become increasingly used as a means of group communication. Since most students have access to WhatsApp, and that is where we relay any crucial announcements. Students may also get information through Microsoft Teams, although it takes them longer to obtain it than WhatsApp. Students now can have a direct channel to the Lab Coordinator to ask any and all queries they might have about the practical implementation of lab procedures through the use of the WhatsApp platform.

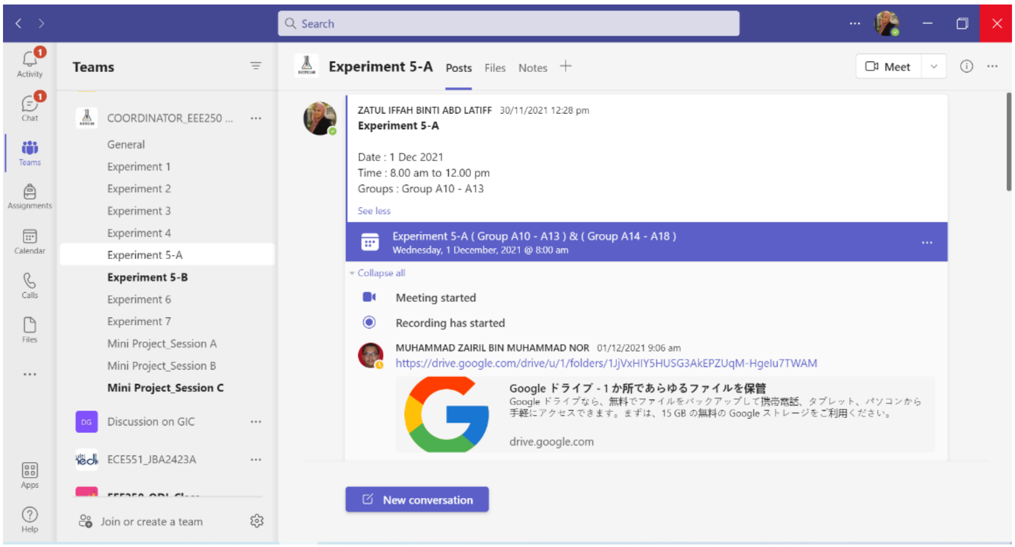
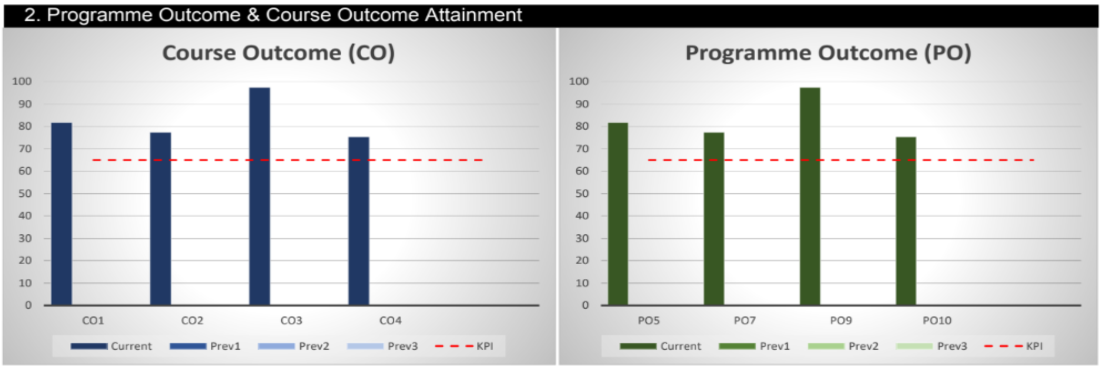


Figure 1. Microsoft Teams group created for Electrical Engineering Laboratory course where online class is conducted and laboratory materials are shared with students

3) PO Attainment Measurement

The OBE-ANAS instrument has been integrated into the measurement approach used for both

diploma courses in order to evaluate students' overall performance in the subject they are studying. Figure 2 illustrates the course outcome and the performance of the programme outcome of the Electrical Engineering laboratory course for students pursuing a Diploma in Electrical Engineering (Power). The tabular representations of the descriptions of each PO and CO, as well as the CO-PO mapping, may be discovered in Tables 1 and 2, respectively. The key performance indicator (KPI) that has been defined for CO and PO is 65%.



1. Course Outcome KPI	65

CO	CO1	CO2	CO3	CO4
Current	81.8	77.4	97.4	75.3
Prev1				
Prev2				
Prev3				

2. Programme Outcome KPI	65

PO	PO5	PO7	PO9	PO10
Current	81.8	77.4	97.4	75.3
Prev1				
Prev2				
Prev3				

Figure 2. Analysis of Programme Outcome (PO) and Course Outcomes (CO) Attainment for Electrical Engineering Laboratory course for Diploma in Electrical Engineering (Power) students

It is possible to deduce from figure 1 that the percentage of the Course Outcome as well as the percentage of the PO for CO1, which is mapped to PO5, is 81.8%. The mapping of CO2 to PO7 shows a percentage of 77.4%, but the mapping of CO3 to PO9 shows a percentage of 97.4%. The percentage for t he mapping of CO4–PO10 is 75.3%. The mapping of CO3 – PO9, which assesses the self-effectiveness of being a member in group activity, has the greatest CO-PO percentage. Since the project needs to be performed in a grouping consisting of at least three individuals, this aspect of the project is evaluated through a mini project. The high percentage of this CO-PO mapping suggests that the members of the team were able to successfully collaborate with one another in order to delegate the mini project. The mapping of CO4-PO10, which examines the element of both written and vocal communication skills, has the lowest percentage of any CO-PO mapping. The performance of the written report for both the laboratory session and the mini project, as well as the presentation of the mini project, is used to evaluate this component. This low percentage suggests that students struggle to convey both their comprehension or their knowledge in either written or verbal form. It is possible that this is related to a lack of knowledge as well as limitations in one's ability to learn the English language, which is used as a medium of language for reporting the experiments. The mapping of CO2-PO7, which indicates the second lowest percentage, is a measurement of the ability to provide an engineering solution to an issue linked to sustainability. This aspect of sustainability is evaluated through a mini project in which students are required to suggest an engineering solution and demonstrate how their proposal relates to the sustainability aspect. The relatively low percentage suggests that the students do not understand how their engineering solution can be connected to the element of sustainability in the challenge that has been assigned to them. The mapping of CO1-PO5, which evaluates an individual's level of hands-on experience with modern engineering tools, holds the distinction of having the second-highest percentage. In each and every experiment, practical skills are measured. The high percentage indicates that students were able to effectively execute the experiment and adhere to the procedures outlined in the laboratory manual.

Figure 3 illustrates how well students in Part 3 of the Electrical Engineering Diploma studies (Electronic) did on the CO and PO analysis. The pattern of the highest and lowest percentages of CO-PO mapping is the same for students enrolled in Diploma in Electrical Engineering (Power). The mapping of CO3-PO9 indicates the highest CO-PO percentage, while the mapping of CO4-PO10 indicates the lowest CO-PO performance. The explanation for the top and lowest performances of the CO and PO % is similar to that which was addressed before in the CO-PO results for students who were pursuing a Diploma in Electrical Engineering (Power). When compared to the Power Student, the CO-PO percentage for students who are pursuing a Diploma in Electrical Engineering (Electronic) seems to be rather low. The mapping of CO1-PO5, which has the second-lowest CO-PO percentage, demonstrates an individual's ability to perform practical skills while utilising the contemporary engineering tools. When compared to students in the Electronics programme, those in the Power programme demonstrate a higher level of practical expertise. The mapping of CO2-PO7 has the second highest CO-PO percentage, which is just a bit higher than the percentage that Power student possesses for this specific mapping. It demonstrates that the student in Electronics can make a connection between their technical solution and the sustainability factor in their small project. Nevertheless, in terms of total CO-PO accomplishment for both programmes, they have exceeded the Key Performance Index (KPI) that was established, which was set at 65%.

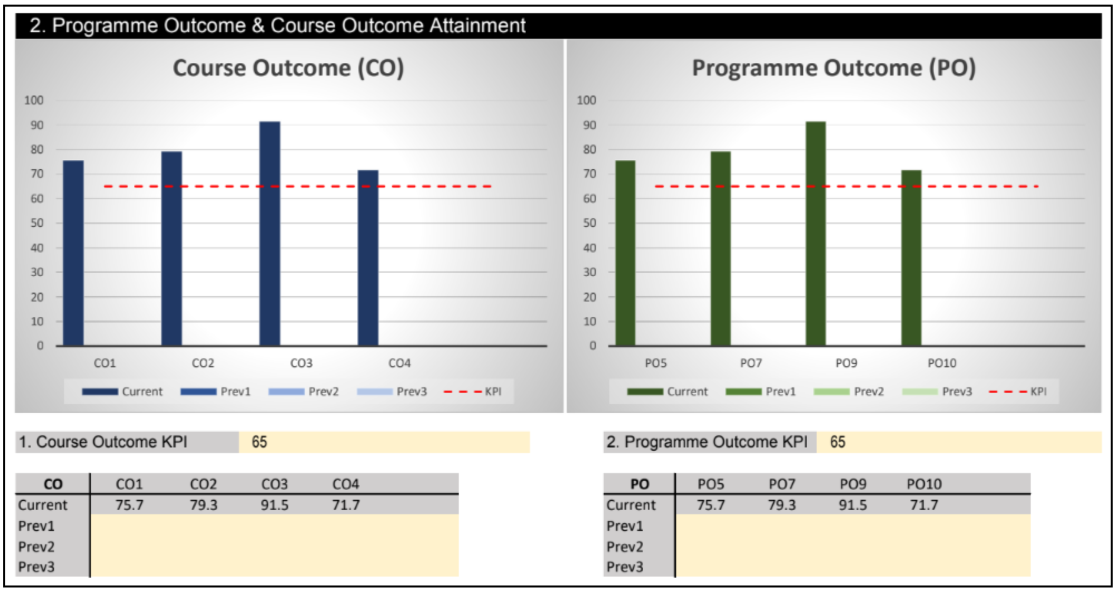


Figure 3. Analysis of Programme Outcome (PO) and Course Outcomes (CO) Attainment for Electrical Engineering Laboratory course for Diploma in Electrical

Conclusion

This study presents the implementation of blended mode (face-to-face and online mode) in Electrical Engineering Laboratory course during the semester of 2021 for two Diploma studies in Universiti Teknologi MARA (Pasir Gudang Campus) – Diploma in Electrical Engineering (Electronic) and Diploma in Electrical Engineering (Power). Students from Part 3 of these Diploma studies who were enrolled in an Electrical Engineering Laboratory Course during this specific semester were those who were engaged in the course. Initially, a methodology was presented, which includes the phases of understanding the structure of the Electrical Engineering Laboratory Course, next to the selection of the compatible educational method and delivery of each experiment, and finally followed by the utilisation of the OBE-ANAS tool as the measurement tool for the performance of CO and PO. The efficacy of the methodology that was adopted may be proven by analysing the significant key that the Electrical Engineering Laboratory course possessed, which lied on the CO and PO that were stated. Therefore, a positive outcome is evidence that the education delivery approach is effective. The CO-PO measurement that was carried out at the end of the semester reveals that the performance of students who are pursuing the Diploma in Electrical Engineering (Power) is higher than the performance of students who are pursuing the Diploma in Electrical Engineering (Electronic). Both of these diploma studies show a pretty great results and moderately passed the KPI that was established for the most significant key element of this topic, which is the practical skills competence in handling modern engineering tools. This suggests that despite the constraints of adopting the online delivery method for parts of experiments, students are still able to convey their practical abilities in a very good way. It's possible due to the careful consideration given to the manner of delivery for both crucial and non-crucial trials. Since of this finding, it is also possible to draw the conclusion that virtual laboratories may be constructed as an accompanying training in technical specialisations; nevertheless, they should not be used as a replacement for actual practical training because as hands-on experiences will undoubtedly be much superior to the virtual mode.

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