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Open distance learning simulation-based virtual laboratory experiences during COVID-19 pandemic

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ABSTRACT

The widespread of coronavirus disease 2019 (COVID-19) pandemic led to a discovery that open distance learning (ODL) has turned out to be the only choice for teaching and learning by most institution (s) of higher learning (IHLs). In Malaysia, ODL is considered a new approach as physical laboratory practice has always been conducted for laboratory courses. This is a quantitative study which explores the perceptions of e-Lab among the students of bachelor's in electrical and electronic engineering (EE) by focusing on the effectiveness and readiness in conducting the e-Lab. Simulation-based model is proposed for conducting the e-Lab using an interactive media and validated with the final score performance. With the future goals of improving the e-Lab in terms of delivering methods and engaging mediums between students and laboratory instructor, this study also discovered the levels of response from students' perception to substitute the conventional laboratory by providing an equivalent and comparable learning experiences of the students.

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1. INTRODUCTION

Engineering education in higher learning institutions plays an important role in developing of the critical elements such as fundamental problem solving, problem-based learning (PBL), ability in designing and constructing new knowledge in students' background for their career preparation. The conventional practice of laboratory session is vital for the students to understand relationship between theoretical concepts and the related practical sciences engineering knowledge by conducting the training experiential. Consequently, the laboratory training has been compulsory in curriculum requirement for academic accreditation by most professional engineering bodies such as engineering councils [1] including the Engineering Accreditation Council Malaysia (2009). As the awareness on engineering education has been revolutionized in designing a new mode of laboratory known as 'virtual laboratory', the recent advancement in information technology is vital to comprehend with the current situation. Such development has generated discussion about the student learning outcome and most importantly the student interest in laboratory learning experiences due to changes by virtual learning mode.

This study describes the students' learning experiences by focusing on studying the effectiveness of virtual laboratories in the School of Electrical and Electronic Engineering (EE) conducted during the coronavirus disease 2019 (COVID-19) pandemic outbreak which require fully open distance learning (ODL) mode including the laboratory work. Meanwhile, the long-term goal of the study is to identify how effective the virtual laboratories or e-Labs are based on the students' acceptance and hence discover their learning outcome performances based on their end of semester results.

2. ELECTRICAL ENGINEERING VIRTUAL LABORATORY

Currently, the worldwide disruption caused by the COVID-19 pandemic has resulted in numerous impacts including on the education environment. The rise of online learning in higher education has led to numerous evaluation and development in distance learning for laboratory activities. Many studies have been conducted to investigate students' acceptance and experience in conducting virtual laboratories [1]–[4], developing potential laboratory experimental [5]–[7] and to investigate the effect of virtual laboratory on students [8]–[10].

At institutions of higher education in Malaysia particularly at public universities, virtual laboratory has not been the primary method in conducting laboratory sessions as the effectiveness of the virtual approach is questionable [11], [12]. According to literature on virtual laboratory or simulation-based laboratory practice in Malaysia, the factors such as the content and curriculum have an affect towards the students' attitude [13] and there is a lack of teaching and learning facilities. This has been proved by the research on students' attitudes towards simulation lab exercise-based that has shown a significant relationship between the attitudes and their preference in simulation software [14]. Mostly, the research on virtual education was primarily conducted at school level for students and focusing on enhancing the subject matters [13], [15]. The only research that having in-depth study on the virtual laboratory at higher education levels was focusing on chemistry [14] and electrical engineering [16], [17]. However, none of these studies have provided final outcomes of the implemented virtual laboratory in terms of student perceptions or laboratory performance towards the course and program output for continuous quality improvement in the laboratory. Hence, this study is proposed to evaluate the students' perceptions and performances on online virtual laboratory for electrical and electronic engineering undergraduate students during COVID-19 pandemic. This study may help to encourage online virtual laboratory for engineering students as an alternative method to replace physical training or face-to-face laboratory meeting.

2.1. Accreditation engineering program

Engineering technology accreditation council (ETAC) is the body under the board of engineer Malaysia (BEM) that is responsible for ensuring the standard and quality of engineering technology programs at institutions of higher learning (IHL) in Malaysia. The emphasize of this standard includes elements of outcomes in the engineering technology curriculum to ensure continual quality improvement (CQI) based on outcome-based education (OBE). The OBE is focused on the outcomes of the students i.e. the achievements of students that are measured and proved by course outcome-program outcome (CO-PO) mapping criteria as set by the accredited body [18]. Hence, the outcomes could be improved based on the CQI performance and analysis for next coming semester. This emphasize the significance of the quality assurance in public and private universities in Malaysia by endorsement that the education system has demonstrated a strong, long-term commitment to quality assurance in producing graduates ready for industry practice at national and international levels [19].

2.2. CQI performance

In this ODL virtual laboratory, the CO-PO mapping is similar to the physical laboratory as shown in Table 1. In these courses, there are two CO namely as CO1 and CO2 that mapping to the respective PO. The mapped CO1/PO4 measure the student ability to explain electronics circuit and electrical system methodology and result based on report writings. Meanwhile the CO2/PO5 measure the student ability to construct electronics circuit and electrical system for electrical/electronic problem using suitable method during the In-lab session. The analysis of students' performance has been evaluated based on these CO-PO mapping as explained in section 4.2.

Table 1. CO-PO mapping for ODL virtual laboratory

Course Outcomes (COs)		Program Outcome (POs)	
CO1	Evaluate electronics circuit and electrical system methodology and result for electrical/electronic problem experiment requirement (C5).	PO4	Ability to conduct investigation into complex electrical/electronic problems using research-based knowledge and research methods.
CO2	Construct electronics circuit and electrical system for electrical/electronic problem using suitable method to meet experiment requirement (P5).	PO5	Ability to create, select and apply appropriate techniques, resources and modern engineering and IT tools, including prediction and modelling, involving complex electrical engineering activities.

As an extension to the CO-PO mapping and evaluation, the quality of the course must be continuously improved by closing the loop in the learning process cycle, particularly at every semester. The CQI is focusing on the improvement of the process, system, or product repeatedly until it meets the customer satisfaction. A variety of standard or framework that can be implemented to achieve the optimum level of quality in the course. In Malaysia, the quality assurance body is known as Malaysian Qualification Agency (MQA) under Ministry of Higher Education and practice standard quality assurance to accredit courses [20]. In the other hand, the CQI is mostly important since all evidence of the course must be related to CQI for the program to be accredited by ETAC [18]. Practically, in physical laboratory, the CQI performance is analyzed at end semester based on the CO-PO achievement and performance of CQI score is set at 65% to represent the course achievement. Section 4.2 analyses the performance of the ODL virtual laboratory based on CQI analyses.

3. DESIGN AND METHODS

3.1. Design of the ODL virtual laboratory

The physical laboratory and the software simulations are being widely used by various global IHLs based on the requirements of the courses in order to academically improve the student capabilities. Generally, there are varieties of virtual laboratory had been proposed as an alternative to the physical laboratory in many areas despite the combination of both as considerable method for higher learning institution. However, in teaching and learning for engineering education, the virtual laboratory is primarily important as the adaptation between physical and virtual environment is totally distinct. Therefore, the consideration on design the approach or virtual laboratory model is crucial and thoroughly model so that the objective of the laboratory is preserved and meet the requirement. Table 2 shows the proposed design approach and model for virtual laboratory in engineering education. Literally, the simulation-based model is significant for electrical and electronics engineering since the simulation tool is capable in most experimental module. Furthermore, the simulation-based model is stand-alone approach which applicable for student with limited internet connection or in rural area since the learning are conducted online.

Table 2. Virtual laboratory for engineering education

Design approach/model	Course
Structural equation modelling	Digital circuits [8], computer technology [3]
Engineering project-based learning	Engineering [21]
Simulation-based model	Electrical engineering [8], electronics-telecommunications engineering [14]
Cognitivist-constructivist-contextual life cycle development model	Chemistry [11]
Web-based	Electrical engineering [22]
Remote-controlled +web-based	Electrical engineering [17], electronics engineering [23], control engineering [24]

Therefore, this study is proposed an ODL virtual laboratory based on simulation model with the consideration of different laboratory courses implemented in undergraduate degree. The virtual laboratory sessions were conducted during COVID-19 pandemic lock down semester which allowed only ODL mode program for students studying degree in electrical and electronic engineering EE200 program. This study is aimed to investigate the acceptance of ODL virtual laboratory conducted based on survey by questionnaire and validated with the students' performance as control group.

3.1.1. Questionnaire

For questionnaire, semester 3, 4, 5, and 6 students in the ODL semester February to July 2020 were asked to fill in the survey. There were overall 130 students from semester 3 to semester 6 involved in this study and these virtual laboratories were their first experience. There are all 4 laboratories conducted on different semester students as shown in Table 3. All the laboratories' works were conducted the ODL approach by computer-based simulation following the schedule as per accredited laboratory credit hour. The laboratory experiments included electrical and electronic measurements covers electronics, power, digital, communication and control system. Each laboratory conducted per semester basis using different simulation tools based on laboratory requirement. Structured laboratory (SL), open-ended laboratory (OEL) and problem-based laboratory were also included for students in semester 5 and 6. The SL laboratory is a type of complete laboratory with structured guidelines and modules, and usually covers fundamental concept in EE while the OEL and PBL is a type of unstructured laboratory which require students to design their own module and methods to conduct the laboratory. The students involved in the study indicates by number of samples, n. All the laboratory courses are following the ETAC standard with non-final exam of 120 student learning time (SLT).

Table 3. The Sample of study conducted on a semester basis for students of bachelor's degree in electrical and electronic engineering (EE200)

Semester	Lab Course Code	Type	Sample (*n*)	%
3	EEE415	Fundamental	33	25
4	EEE515	Fundamental	49	38
5	EEE525	SL and OEL	9	7
6	EEE535	OEL and PBL	39	30
		Total	130	100

In addition, inspired by the study in [1], a survey of questionnaire with both closed and open-ended questions was designed with some adaption to the current laboratory courses requirement and the collected data investigates student perceptions and their experiences of virtual laboratory. The questions using a 5-point likert scale (scores of 1-5 were used to indicate levels of agreement) consists of 3 parts that are students' experiences, students' challenges, and recommendation from students towards improving the virtual laboratory.

3.1.2. Design of ODL virtual laboratory concept

The conceptual of the ODL virtual laboratory is designed based on ETAC standard requirement tally with the physical laboratory conducted before COVID-19 pandemic scenario to complement the science, computing and engineering theory [19]. Generally, the ODL virtual laboratory design is applicable for all laboratory courses of SL, OEL and PBL for the engineering program. The complete experimental design process for using an ODL virtual laboratory is shown in Figure 1.

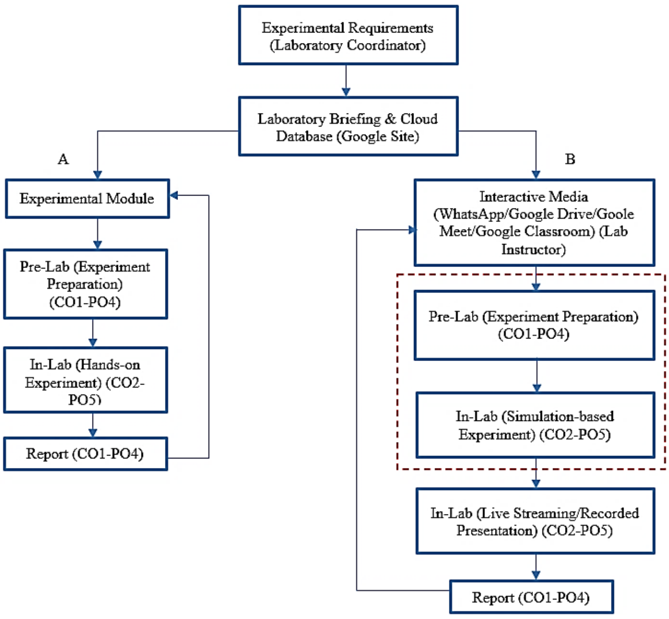


Figure 1. Comparison between the physical laboratory process (flow A) and designed simulation based ODL virtual laboratory (flow B)

Conventionally, the process of physical laboratory conducted before the COVID-19 pandemic is shown as flow A which demanded students to achieve two course outcomes (CO1 and CO2) that mapping to PO4 and PO5 respectively. The Pre-Lab task is prepared before physically conducting the experiment and demanded student to hand-in during the day of in-lab session. Whilst the laboratory report is required to be submitted after the In-Lab session depends on the laboratory course requirement. Therefore, the sequential process of ODL virtual laboratory is designed as flow B in order to adapt the physical laboratory process with minimal changes. In addition, it should be mentioned that flow A, presented the conventional experiments in physical laboratory, is adaptably alike the process shown in flow B, offered by the virtual experiment platforms meant for online and distance learning. Without compromising any physical movement during pandemic, this design is perhaps to ensure a sustainability in higher education learning for laboratory work. Generally, most of the laboratory modules are simulation-based experiment but in-case for non-simulation modules which require specific tools or equipment, a recorded video module is used to replace the simulation module. However, the overall ODL laboratory process is sequentially looped as flow B.

3.2. Development of computer simulation-based virtual laboratory

The laboratory modules for all experiments have been revised accordingly into computer simulation-based experiments to adapt the physical laboratory modules. The electronic simulation tool is a high-performance simulator for general circuit simulation and user-friendly tool which adaptable to different experimental task such as LTSpice, Multisim or MATLAB. Students can install the simulator once and perform different experimental items to operate by referring the laboratory module anytime and anywhere through their computer.

Based on physical laboratory reference as shown in Figure 2(a), the laboratory is transformed virtually as depicted in Figure 2(b) where the Google Classroom platform is used as interface for pre-Lab and reports submission as shown in Figure 2(c). Meanwhile, Google Meet is the real-time communication medium used for student's demonstrate their experimental work according to their presentation schedule as shown in Figure 2(d). This method is significantly effective and secure since every student belongs a student account and the cloud storage could help to minimize hard storage besides the open sharing option. This way of communication is also helping the lab instructor to closely monitor the student work and able to track the progress in large number of students for the course.

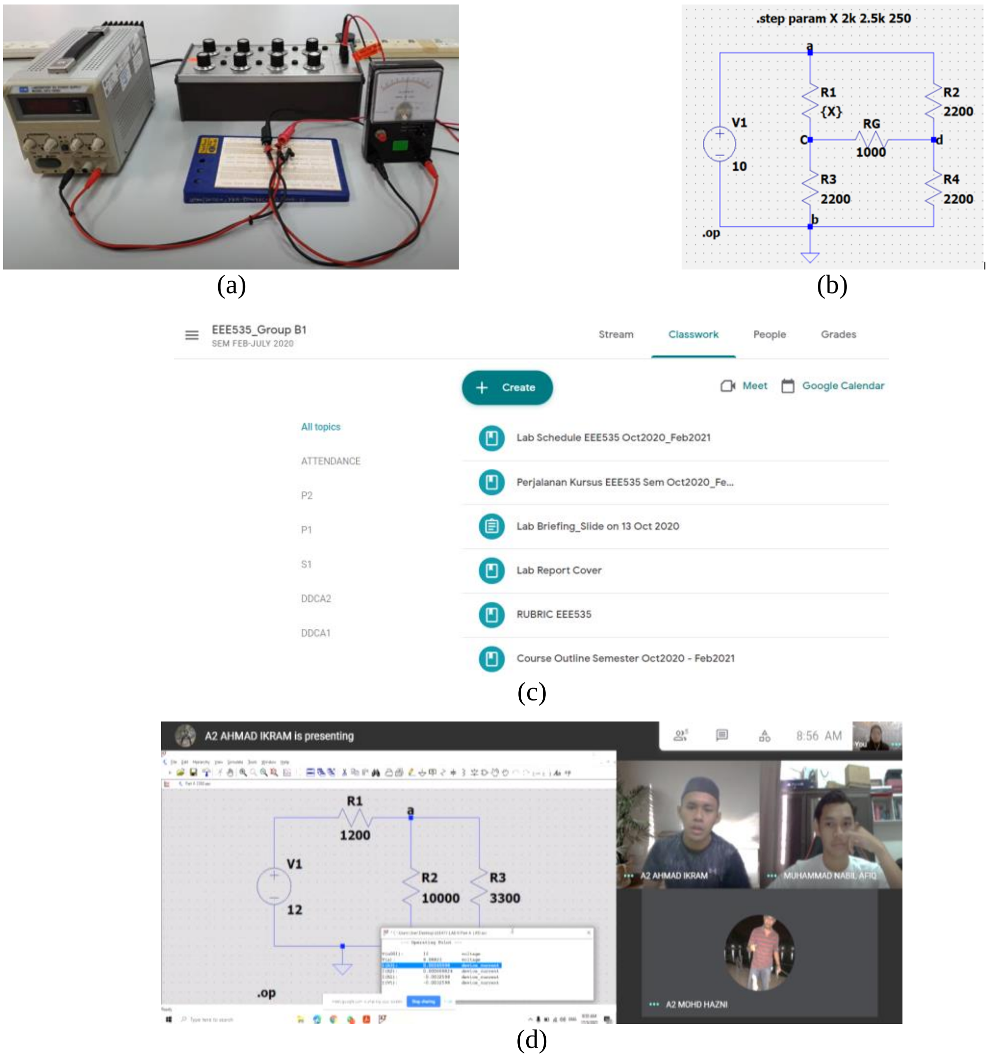


Figure 2. The process of simulation-based virtual laboratory (a) physical experimental environment set up and obtainable result, (b) simulation-based experimental of the virtual laboratory and corresponding result, (c) pre-Lab and report submission platform for virtual laboratory, and (d) live streaming of experimental demonstration for in-lab presentation

3.2.1. Amendment on rubric

In order to adapt between physical laboratory and the ODL virtual laboratory, the grading of the laboratory evaluation was conducted based on the rubric which followed the ETAC standard. All the experimental assessments for pre-Lab, in-lab and report are evaluated based on scoring guide or rubric as shown in Table 4.

Table 4. ODL virtual laboratory rubric amendment parallel to the physical laboratory

Assessment	CO-PO	Criteria physical laboratory rubric	Criteria ODL virtual laboratory rubric
Pre-Lab (10%)	CO1-PO4	– Design and formulate the experiment task and procedure – Prepare the table for expected result – Understanding of suitable tools to be used	
In-Lab (50%)	CO2-PO5	– Ability to handle equipment	– Ability to handle the experimental tools
		– Understanding of experiment	– Understanding of experiment
		– Efficiency in taking data	– Efficiency in taking data
		– Time management	– Presentation Skills (time management, organization, speaking skill, convincing)
		– Communication skill (Individual Q&A)	– Ability to answer question (individual Q&A)
		– Disciplines (dress code, follow lab regulation and safety)	– Task completion according to module requirement
		– Participation (by observation) – Tidiness (preserve the cleanliness of workplace and equipment) – Workmanship (Organization of work)	
Report (40%)	CO1-PO4	– Report procedures (General format and structure/Clear and concise procedures) – Complete block diagram or circuit or flow chart (Results Presentation/Results in the forms of data and graph) – Data analysis (Interpret and analyze the results) – Answer the question in the lab sheet. – Conclusion – Answer the objectives	

3.2.2. Implementation ODL virtual laboratory

The practice on physical laboratory conducted before COVID-19 pandemic has been that students must attend the laboratory session based on the lesson plan provided by the university. In a semester, a total of 14 weeks allocated for the practical and learning process which in week 1 and 2 are normally provided for preparation and briefing. Practically, the implementation of the ODL virtual laboratory is conducted based on similar framework of lesson plan with minimal amendment on process flow as shown in Table 5.

Table 5. An example of lesson plan for ODL virtual laboratory

Lesson Week	Stage	Participants	Specifications
Week 1-2	Preparation and Online Briefing	Coordinator	Preparing laboratory schedule, rubric and guidance, Briefing/Introduction to the course and virtual laboratory
		Lab Instructor	Prepare virtual laboratory module, prepare communication medium for students works
		Students	Course registration and get familiar with the simulation tools,
		Interaction	Online question and answer
Week 3-13	Before Lab	Lab Instructor	Release the experiment module and materials,
		Students	Get familiar to the virtual laboratory (Read the manual and/or watch the introduction video of the experimental module and run the demo of the experimental module) Submit Pre-Lab Prepare the simulation of experimental work
		Interaction	Online communications between students and teacher, as well as between students and students
	Online Lab	Lab Instructor	Virtual laboratory discussion and evaluation
		Students	Virtual laboratory demonstration and presentation
		Interaction	Online question-and-answer
	After Lab	Lab Instructor	Notify report submission and evaluate report
		Students	Enhance simulation of experimental work Submit report
Week 14	Final evaluation	Coordinator	Summary and evaluation of students' overall performance
		Lab Instructor	Review and final evaluation
		Students	Notification all complete modules.

3.3. Validation with a control group

The survey is conducted to investigate the students' perception and experience on ODL virtual laboratory. This survey is divided into three parts of demographic survey, students' perception and experience on virtual laboratory as described in Table 6. The finding of the study is further discussed in section 4.1.

Table 6. Virtual/e-Lab perception

Survey questions (virtual/e-Lab experiences)	Description	Survey Questions (virtual/e-Lab challenges)	Description
I found the virtual/e-Lab session is:		I preferred lab manual instruction in:	Laboratory module
Easy to operate/conduct	Simulation tools and its processing	I preferred to present my lab demonstration in:	In-Lab demonstration/ experiment
Easy to understand	Laboratory module	Time given to complete the virtual/e-Lab is sufficient?	Laboratory time allocation
Flexible to use anytime/anyplace	Laboratory management	How long do you need to complete the lab before presenting it?	Laboratory time management
Satisfying	Satisfaction over virtual laboratory	I preferred to conduct each virtual/e-Lab with	Teamwork/group member
I think virtual/e-Lab is:			
More suitable for senior students (2nd year/above)	Suitability/seniority		
More understand and learnable than traditional/f2f lab	Satisfaction over virtual laboratory		
Virtual vs physical lab:			
I (will/will not) use the virtual laboratory workshop outside lab hours for distance learning	Agreement on virtual laboratory		

The performance of students was measured for all attended laboratories work and average as the final marks. Meanwhile, the overall performance to evaluate between virtual and traditional laboratory method is compared by analyzing the CQI index for each laboratory course. In Malaysia, the CQI model is primarily used for maintaining and improving the higher education quality as the practice in most public and private universities assured by MQA under ministry of higher education [20], [25]. The model has been developed to directly address the PO of the educational objectives and incorporate certain specified outcomes [8]. Students were evaluated based on laboratories rubrics assessment of 10% pre-Lab, in-lab 50% and short report 40% with respective CO and PO for all laboratories as explained in section 2.2.

4. RESULTS AND DISCUSSION

4.1. Survey on students' perceptions

The results of the survey questions indicated that the virtual laboratories based on fully computer simulations were generally well-received with almost 60% students agreed to use virtual laboratories as shown in Table 7. The result indicates that *m* is the number of students and also represent by percentages calculation. Moreover, responses also indicated that students perceived virtual lab as being easier to operate and conduct, easy to understand and flexible to use at any time. There was a consensus that virtual laboratories are more suited to senior students in second year and above.

Table 7. Percentage of students who indicated strong agreement to disagreement in virtual/e-Lab experiences during a semester

Survey questions (virtual/e-Lab experiences)	*m* (%)					
I found the virtual/e-Lab session is:	(*n*)	SA	A	N	D	SD
Easy to operate/conduct	130	10 (8)	34 (26)	49(38)	24 (19)	13 (10)
Easy to understand	130	5 (4)	40 (31)	49 (38)	21 (16)	15 (12)
Flexible to use anytime/anyplace	130	19 (15)	59 (46)	32 (25)	11 (9)	9 (7)
Satisfying	130	11 (9)	35 (27)	56 (43)	17 (13)	11 (9)
I think virtual/e-Lab is:	(n)	SA	A	N	D	SD
More suitable for senior students (2nd year/above)	130	8 (6)	21 (16)	65 (50)	24 (19)	12 (9)
More understand and learnable than traditional/f2f lab	130	7 (5)	15 (12)	50 (39)	41 (32)	17 (13)
Virtual vs physical lab	(n)		Will		Will not	
I (will/will not) use the virtual laboratory workshop outside lab hours for distance learning	129		77(59.7)		52(40.3)	

The respondents were also agreed with the flexibility of virtual laboratory by more than 50% and generally satisfied with the conducted virtual laboratory. The followings are some of students' experience in handling the virtual laboratory: *'e-Lab is good for me. I can explore so many things, simulation, or any information that I don't know, I'll search in Google, watching demo in YouTube and discuss it together with my classmate. We can gain knowledge during the process. And e-Lab using Simulation also provide the accuracy in data/result. Since, some of our electronic components in laboratory are not really function well, it will give little affects for our traditional lab'*

The main challenge faced by the students to perform the virtual laboratory is the internet connection. Other than that, the understanding of the laboratory instruction also contributes to the problems as there are different experimental modules to be completed on each lab courses. From the survey, most students were preferred to have virtual laboratory manual instruction in PDF/word sheet. In the survey, the following results responded to problems experienced by students while handling the virtual laboratory. *'Indeed, this virtual e-Lab is quite hard for me. I'm the kind of person who cannot work alone on something especially on things that I've never done before'*

According to Table 8, the students equally prefer to present their work by video recorded and through live streaming. It is believed that students who experience poor internet connection were indicated by 14.1% option to present their work through email. Other than that, the students were agreed that the duration given to complete their virtual laboratory is adequate within 2 to 3 days of 3 members per group.

Table 8. Percentages of students who indicated strong agreement to disagreement in virtual/e-Lab challenges faced during semester February-July 2020

Survey questions (virtual/e-Lab challenges)	*(n)*	*m* (%)				
		Video recording	PDF/ word sheet	Live streaming	Phone call	Email
I preferred lab manual instruction in:	129	51 (40)	61 (47)	17 (13)	NA	NA
I preferred to present my lab demonstration in:	128	57 (45)	NA	53 (41)	NA	18 (14)
Time given to complete the virtual/e-Lab is sufficiently enough?	130	Yes 52 (40)	No 28 (22)		May be 50 (39)	
How long do you need to complete the lab before presenting it?	129	1 day 13 (10)	2-3 days 44 (34)	4-5 days 36 (28)	> 5 days 26 (20)	Others 10 (8)
I preferred to conduct each virtual/e-Lab:	129	Alone 2 (2)	2 members 24 (19)	3 members 90 (70)	4 members 13 (10)	

4.2. Validation with a control group on students' performance

The students' performance of end-semester scores for all laboratory courses of EEE415, EEE515, EEE 525 and EEE535 are shown in Figure 3. The results were evaluated based on all students enrolled the laboratories courses this semester. The results show that most students scored excellent grades from A to B and only few with C and C+ grade. Generally, the good performance results obtained by EEE415 and EEE535 were the most outperform compared to the difference results showed in EEE515 and EEE525. This is showing that virtual laboratory is suited to all semester's students and the year of students has not affected the student's performance at all. However, none of students were scored in A+ and C-.

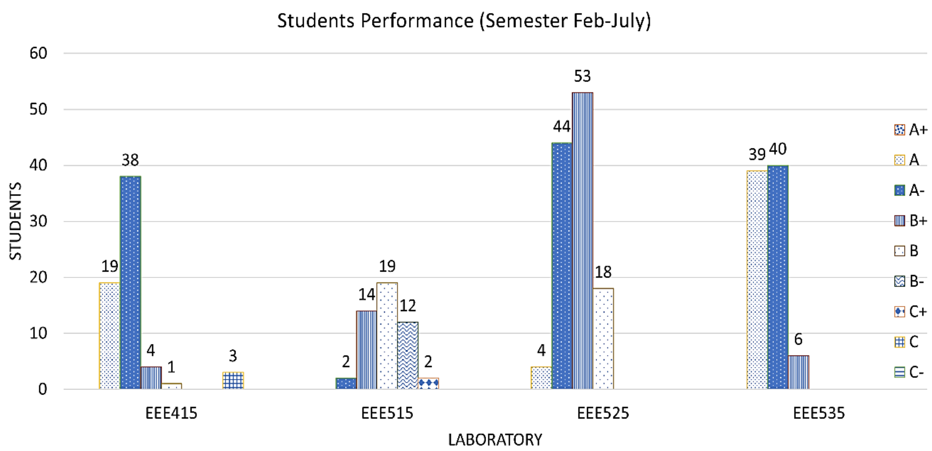
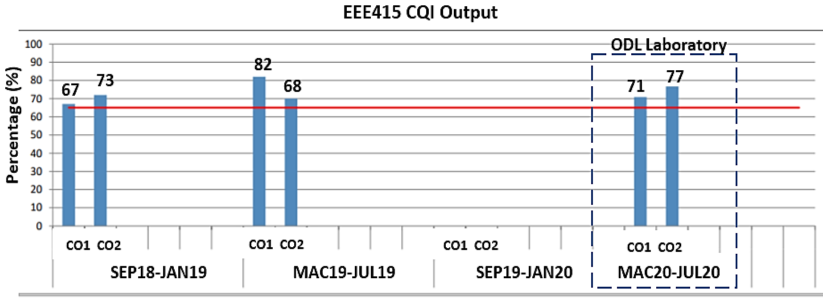
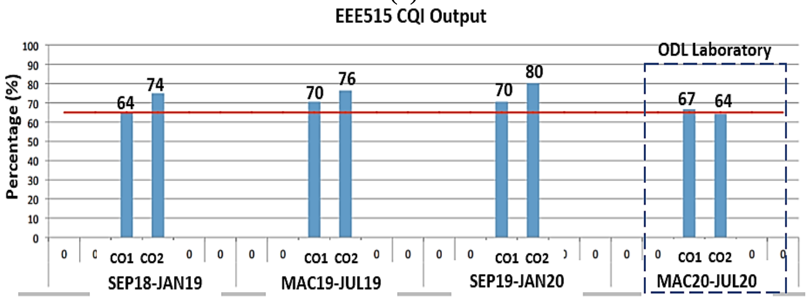


Figure 3. Performance of end-semester scores based on laboratory courses EEE415, EEE515, EEE525 and EEE535

Generally, from the results, it shows that the CO2/PO5 performances for virtual laboratories (marked as square box) in EEE415 has been increased compared to conventional laboratories conducted on previous semester as depicted in Figure 4(a). This is showing that the ability of students taking the virtual lab or simulation-based laboratories is adaptably changing from traditional laboratory. Although result from EEE515 as depicted in Figure 4(b) slightly lower in CQI performance, the CO2/PO5 measure showing that virtual laboratories mode changing is acceptable and adaptable among EE students. Figure 4(c) and 4(d) show similar trend for EEE525 and EEE535 CO2/PO5 performances in virtual laboratories that has increased compared to conventional laboratories. However, as reported, there were several semesters which the course code has not been offered as no student intake in that enrollment semester. In actual, the CQI performance is practically compared by at least 2 consecutive semesters within the same curriculum content to attain the course achievement and improvement plan.



(a)



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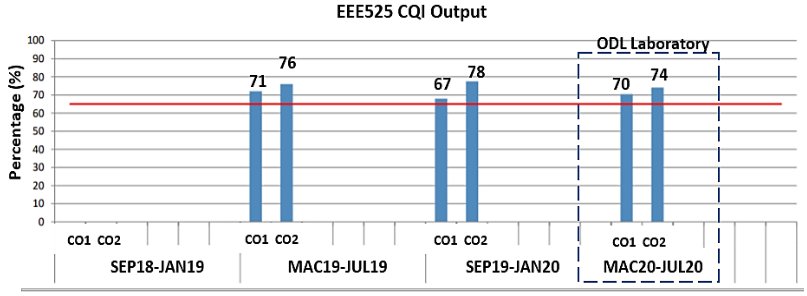

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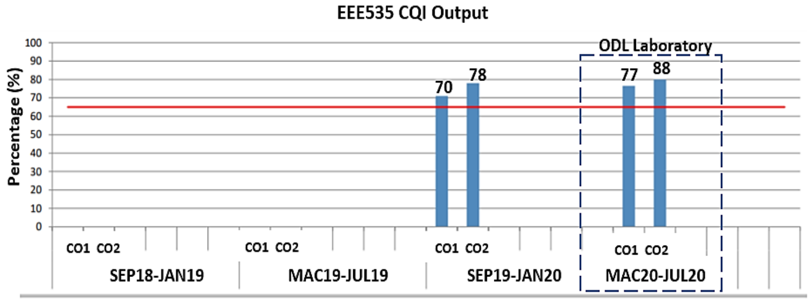

(d)

Figure 4. Comparison of physical and virtual laboratory CQI performances (a) EEE415, (b) EEE515, (c) EEE525, and (d) EEE535

However, the CQI which mapping outcomes of CO1/PO4 that measured the ability of students reporting the laboratories based on their writing skills were decreased for all the laboratory courses. As expected, the reasons might be due to lacking in teamwork between group members as the laboratory report is based on group and the distance discussion may also contributes to the presented results. This fact is supported by the questionnaire findings where about 15.2% were having problem with team member whilst 11.2% were unable to work in long distance. This scenario shows that the students' readiness to adapt virtual laboratory or simulation-based laboratory may requires the important roles of the teachers or lab conductor by thorough planning throughout the semester.

5. CONCLUSION

The purpose of this study was to explore the student perceptions of conducting EE laboratories based on computer simulation tools during ODL semester due to COVID-19 pandemic. This study shows a significant on students' adaptability on changing from conventional physical laboratory to virtual laboratory. Despite several challenges faced on conducting virtual laboratory, there is limitation of the study which regarding to in equivalent ratios between sample sizes represented for each laboratory's courses. Therefore, there is a need to continue this line of research with an equivalently larger sample for each laboratory's courses and continuity in same basis for next ODL semester. There are several limitations of virtual laboratory such as discourage students from becoming familiar with real devices and physical instruments. Moreover, the most important transferable skills of teamwork and communication skills which usually developed and delivered in physical laboratory may diminish due to the remote access in virtual laboratory. Alternatively, further work may be required in designing the syllabus content for virtual laboratory to incorporate collaborative elements and discussions to enhance students' skills.

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