

## Measuring the Learning Effectiveness in the Cognitive, Affective, and Psychomotor (CAP) Domains in Electrical Engineering Laboratory Courses Using Online Delivery Mode: Universiti Teknologi MARA

A'zraaAfhzan Ab Rahim<sup>1</sup>, Ng Kok Mun<sup>1\*</sup>, Azilah Saparon<sup>1</sup>, Ahmad Fadzli Nizam Abdul Rahman<sup>2</sup> and Norlida Buniyamin<sup>1</sup>

<sup>1</sup>*School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia*

<sup>2</sup>*Faculty of Information and Communication Technology, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 UTeM, Durian Tunggal, Melaka, Malaysia*

### ABSTRACT

Online laboratories have been conducted in Malaysian universities using video demonstrations, virtual or simulation tools, or/and remote laboratories. Recent studies on online engineering labs mainly focused on the student learning experience, facilities, and teaching quality. The literature review indicated that the effectiveness of online laboratory learning should be approached from the cognitive, affective, and psychomotor (CAP) domains. The perceived effectiveness of these learning domains will help practitioners identify learning gaps in current practices. This study aims to measure learning effectiveness in CAP using the perceived CAP tool in electrical engineering online laboratory courses in a Malaysian public university. Three electrical and electronics online laboratory courses were selected. A survey questionnaire based on perceived CAP was distributed to 273 students and received 139 responses, a 50.92% response rate. The measured data were analyzed using descriptive statistics and reliability analysis in SPSS. The survey results

suggest that affective learning is enhanced. However, psychomotor learning efficiency is badly affected when the delivery mode of the laboratory course content is changed from physical face-to-face to total online delivery. The evaluation of the effectiveness of cognitive learning was inconclusive due to the limitation of sample size in this area to enable accurate measurement.

*Keywords:* Online laboratories, perceived affective, perceived cognitive, perceived psychomotor

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#### E-mail addresses:

[azraa@uitm.edu.my](mailto:azraa@uitm.edu.my) (A'zraaAfhzan Ab Rahim)

[ngkokmun@uitm.edu.my](mailto:ngkokmun@uitm.edu.my) (Ng Kok Mun)

[azilah574@uitm.edu.my](mailto:azilah574@uitm.edu.my) (Azilah Saparon)

[fadzli@utem.edu.my](mailto:fadzli@utem.edu.my) (Ahmad Fadzli Nizam Abdul Rahman)

[nbuniyamin@uitm.edu.my](mailto:nbuniyamin@uitm.edu.my) (Norlida Buniyamin)

\*Corresponding author

## INTRODUCTION

In December 2019, an unknown virus (now called COVID-19) in Wuhan, China, started spreading worldwide, leading to a worldwide pandemic ("Coronavirus:the first three months as it happened", 2020). The pandemic has caused more than 191 million infections and more than 4 million deaths worldwide ("COVID live update:179,937,394 cases",2021). The COVID-19 pandemic quickly led to the closure of universities and colleges to curb the spread of the disease (Murphy, 2020). Consequently, educational institutions in Malaysia quickly adopted e-learning under the online distance learning (ODL) mode in all institutes of higher learning (Tan, 2021).

In the Malaysian Institution of Higher Learning (IHLs), engineering laboratory sessions normally conducted in a traditional face-to-face setting were no longer viable as students were no longer on campus during the pandemic period. March 2020 marks students' first semester to migrate to an online delivery method compared to traditional physical presence at the labs. This migration occurred worldwide, where laboratory courses were made online to replace the conventional offline mode during the pandemic (Monash University, 2021). Before the pandemic, online laboratories were conducted in some institutions via virtual labs, remote control labs, or video-based labs (Zhai et al., 2012). For virtual labs, simulation tools and virtual reality are used. Online laboratories enable students to access and perform the experiments in the lab remotely. On the other hand, video-based activities provide a step-by-step overview of a real lab so that students can visualize the whole experimental process and its outputs through a video demonstration. These methods have now been widely adopted during the pandemic period.

Gamage et al. (2020) reviewed the transition of offline laboratory courses to online methods during the pandemic. The authors presented the challenges of online laboratories and the impact on assessment activities and student experiences. One of the immediate challenges with online laboratories is the difficulty of achieving hands-on practical skills effectively. Lewis (2014) reported that the performance of examinations of the virtual laboratory tools in biological sciences was equally effective as traditional laboratories in increasing student knowledge and understanding as they facilitate active, inquiry-based learning. However, the main pitfall is their inability to provide individual hands-on experience in using lab equipment. Based on the findings of (Gamage et al., 2020; Lewis, 2014), it can be assumed that learning outcomes that will most be affected when an engineering laboratory course is delivered online will be the loss of psychomotor skills and competencies.

The effectiveness of these online courses has been measured in terms of technology readiness, learning experience, quality of teaching, and communication (Khanna & Prasad, 2020; Lau & Sim, 2020). Chan and Fok (2015) evaluated student learning experience in the virtual laboratory through a perception survey. A survey questionnaire with both closed

and open-ended questions was designed, and data were collected to compare students' perceptions of virtual and traditional laboratories. Similarly, Kapilan et al. (2020) developed and circulated a survey among students to gather feedback on their learning experiences after completing their fluid mechanics virtual lab. Based on the survey, 90 percent of the participants were happy about the virtual laboratory and expressed that their learning process improved with virtual laboratory experiments.

Davies (2008) reported that laboratories enable students to (a) develop experimental, design, problem-solving, and analysis skills; (b) develop data-recording and analysis skills; (c) develop communication and interpersonal skills; (d) develop technical judgment and professional practice and (e) integrate theory and practice. These learning attributes can be categorized into the cognitive, affective, and psychomotor (CAP) domains introduced by Bloom (1956). A more recent elaboration of CAP domains can be found in Tomei (2010). The cognitive domain involves the learning and application of knowledge (Bloom, 1956; Bennett et al., 2016). The affective domain addresses the acquisition of attitudes and values (Kratwohl et al., 1956; Taneri, 2017), and the psychomotor domain focus on the development of the body and the skills it performs (Jewett et al., 1971; Ahmad et al., 2018). Hence, it would be more sensible to measure the effectiveness of learning using the CAP learning domains in online laboratory courses.

Perceived CAP learning domains are a good way to measure CAP attainments independent of course content, grades, institution, and other factors. The method is solely based on students' perception of how much they have learned. The measurement and evaluation of CAP domains are usually conducted using students' grades (Cooper & Higgins, 2014; Mohd Nor et al., 2020). This is the current practice in many online and offline courses. However, this method may not reflect what students learned, and the evaluation is constrained by institution, course content, and inconsistencies of instructors (Rovai et al., 2009). Rovai et al. (2009) introduced a perceived CAP that measures the attainment of these learning domains from the students' perception, independent of limitations imposed by course content, instructor assessments, and institution. In 2018, this instrument was used by Horning (2018) to examine the perceived CAP learning of students using open educational resources in face-to-face and distance education courses at nine community colleges in the southeastern United States. It has been used to evaluate CAP learning in the clinical skills training conducted via ODL (Kawasaki et al., 2021) and assess bakery skills required by students during industrial training (Rachmawati et al., 2019). Khidzir et al. (2016) used perceived CAP learning to study the viability of implementing virtual learning in various fields.

However, based on the review, it can be observed that perceived CAP learning in online laboratory courses related to the teaching of engineering, science, and technology during the pandemic has not been conducted extensively. Most CAP perception surveys

focused on non-technology fields and were more general (Rovai et al., 2009; Horning, 2018; Kawasaki et al., 2021; Rachmawati et al., 2019; Khidzir et al., 2016). Other perception surveys concentrate only on the technology readiness, facilities, and quality of teaching (Khanna & Prasad, 2020). Though evaluation of online laboratory courses in engineering has been done (Chan & Fok, 2015 & Kapilan et al., 2020), it mainly focuses on the student learning experiences. They did not assess the perceived CAP domains of learning.

It is believed that investigating CAP domains for online laboratory courses may help practitioners evaluate whether their online laboratory courses can achieve the CAP domains' learning outcomes. The cognitive, affective, and psychomotor learning domains include knowledge of the subject matter, experimental design, problem solving and analysis skills, hands-on competencies, data collection and analysis, interpersonal and communication skills, ability to relate theory and practice, valuing of occupational safety, and health, professional attitudes, and ethics and ability to collaborate with others. These attributes have not been studied in-depth by others. They could reveal whether students have learned the CAP effectively in the online laboratory course, particularly in engineering, science, and technology. Given the need to evaluate the perceived CAP achievement of learning in engineering, science, and technology online laboratories, this study aims to measure and evaluate the perceived effectiveness in the CAP domains of learning in electrical engineering online laboratory courses in a Malaysian public university.

## **METHODOLOGY**

After the objective has been identified, the next step is to identify the sample selection to evaluate the achievement of CAP learning domains. A quantitative study was conducted to answer the research questions posed in this study.

### **Sampling Technique**

An online survey questionnaire (non-experimental design) was designed and administered to 273 students in the EE241 Electronics Engineering and EE242 Electrical Engineering degree program at the School of Electrical Engineering, Universiti Teknologi MARA, Shah Alam, Malaysia for the Semester March-August 2021. The online survey was emailed to the chosen respondents in July 2021. The survey is anonymous, and participation is voluntary. The survey questionnaire is explained in the next subsection.

Due to the COVID-19 pandemic, many students have not previously experienced being in a face-to-face lab session at the university. Students from semesters 2, 3, and 4 who were chosen as the respondents for this research are students from three laboratory courses, which are Electrical Engineering Laboratory II (EPO423), Electrical Engineering Laboratory III (EEE430), and Electrical Engineering Laboratory III (EPO562). The laboratory courses

enhanced students' theoretical knowledge and practical skills in using basic electronic and electrical components, handling equipment, and measurement techniques. However, due to the pandemic, the content of these courses was delivered using videos and simulation software.

For example, during a normal face-to-face lab session, one of the experiments was Printed Circuit Board (PCB) Fabrication. Students underwent a complete PCB fabrication process, such as transferring the PCB layout to a transparent sheet, preparing an FR4 board, and fabricating the PCB using an ultraviolet (UV) light exposurer, developer, and etching machine. Nevertheless, due to the pandemic, the hands-on exposure to the PCB process was replaced by a video demonstration. A question arises, will the students be aware of health and safety issues by watching an experiment via a video? Online experiments allow multiple runs and extreme variable settings without physical consequences. It might decrease students' perception of risk and danger to themselves or operating equipment wrongly, which may lead to danger or destroy the equipment in an actual physical laboratory. Another example is a student physically in the labs who could be triggered to switch on vents if there are fumes and put on safety glasses if they feel the vibration. As the labs were conducted online, other experiments involving physical measurement from real equipment have been substituted with various simulations using software such as MATLAB and Simulink, Scilab, PSIM, and FEMM.

### **Data Collection Instrument**

A closed-ended survey questionnaire was designed to address the gaps in the literature review. The survey questionnaire was deployed to the chosen sample of respondents using Google Forms to collect responses from students on their perceived attainment in cognitive, affective, and psychomotor (CAP) learning during these online laboratory sessions.

The survey questionnaire consists of two sections. The first section consists of basic demographic questions such as gender, year of study, experience in a physical lab, students' literacy, and communication proficiency. The second section consists of CAP questions developed by adapting and improvising existing, proven perceived CAP questions (Rovai et al., 2009; Chowdury et al., 2019; Kapilan et al., 2020; Chan & Fok, 2015; Rachmawati et al., 2019), and some questions were added to address certain CAP based on expert advice. Originally, there were twenty-two questions for evaluating CAP perception using a 5-point Likert scale (where scores of 1 to 5 were used to indicate levels of agreement with the statements). However, nine questions were removed after the reliability and validation process using SPSS. In the end, 13 questions remain, as listed in Table 1, after performing Principal Component Analysis (PCA) and Exploratory Factor Analysis (EFA) using SPSS. Items reliability was verified using Cronbach Alpha and achieved a reliability value exceeding 0.7.

Table 1

*Questionnaire of student CAP perception on online laboratory*

Questions	Survey Items	Label
I1	I cannot produce a course study guide (compilation of topics, exercises, and learning activities) for future students	C1r
I2	I cannot organize my tasks, apply appropriate methods and solve related problems to achieve the desired outputs	C2r
I3	I cannot relate the online lab experiments to fundamental concepts and theories	C3r
I4	I cannot complete the online lab independently	C4r
I5	I cannot complete all the required group tasks effectively and timely	C5r
I6	I am actively involved in the learning process through the online lab.	A1
I7	I can communicate my findings and results through reports and oral presentations	A2
I8	I can collaborate well with others in my group	A3
I9	I am aware of the safety requirements when working in a physical lab compared to an online lab	A4
I10	I can perform the online lab experiments multiple times, unrestricted by laboratory space, rules, and safety concerns	P1
I11	I can visualize the procedure for using the lab's equipment through the online lab videos	P2
I12	I can demonstrate to others the physical/technical skills learned in this course	P3
I13	I can operate actual equipment confidently after conducting online lab experiments using simulated/virtual equipment	P4

Items I1 to I5 are negatively worded to ensure students respond to the survey honestly and have more reliability in terms of measurement after being reverse coded. The questions (Table 2) used in this instrument were mapped to the closest attributes in one of the three CAP learning domains, as shown in Table 2. Each domain is represented by questions that refer to the domain's lower and higher learning levels.

Table 2

*Attributes of CAP domains of learning for online laboratory*

Cognitive	Affective	Psychomotor
<ul style="list-style-type: none"> <li>• Ability to relate theory and practice <b>(I3)*</b></li> <li>• Ability to collect and analyze data <b>(I2, I4, I5)*</b></li> <li>• Ability to analyze and solve problems <b>(I2, I3, I5)</b></li> <li>• Ability to understand and apply knowledge independently <b>(I3, I4)**</b></li> <li>• Ability to organize knowledge <b>(I1, I2) **</b></li> </ul>	<ul style="list-style-type: none"> <li>• Ability to regulate attitude of learning <b>(I6)*</b></li> <li>• Ability to collaborate with others <b>(I8)*</b></li> <li>• Ability to communicate results and findings <b>(I7)*</b></li> <li>• Ability to communicate effectively with instructor/peers <b>(I7)*</b></li> <li>• Ability to evaluate learning experience <b>(I6, I9)*</b></li> <li>• Ability to value safety and ethics <b>(I9)***</b></li> </ul>	<ul style="list-style-type: none"> <li>• Ability to demonstrate the practical skills learned <b>(I12)**</b></li> <li>• Ability to perform laboratory work safely <b>(I10)***</b></li> <li>• Ability to handle actual equipment after learning simulated/video-based experiments <b>(I13)***</b></li> <li>• Ability to conduct experiments via guided responses <b>(I10, I11, I12)*</b></li> </ul>

Referred and elaborated from: \* (Davies, 2008) \*\* (Rovai, 2009) \*\*\* New attributes

### Data Handling and Analysis

The data collected from the approved questions were stored securely in Google Drive, which requires secure access. As the questions were all set as compulsory, all respondents answered all the questions. Hence, there are no outliers in the data. Subsequently, the data were exported for further analysis.

Reliability tests were conducted to ensure the consistency of the data collection instrument. Confidence interval and margin of error were checked to ensure that the data obtained and the estimation of the location of a statistical parameter was true for the population (Taherdoost, 2017).

Lastly, descriptive and inferential statistics were used to analyze the collected data. The data were analyzed by the median, lower and upper quartile of each item and the distribution of responses, i.e. (percentage (%) that agree, disagree). Data on the number of students with experience in a physical lab and students who do not have physical lab experience were compared. Mann-Whitney U-test was conducted to investigate whether a significant statistical difference exists in students' confidence to operate actual equipment between those with and without physical lab experience (I13). Other demographic data such as gender, year of study, students' literacy, and communication proficiency are not used in this study and are reserved for future studies.



## RESULTS AND DISCUSSION

This section discusses the results in greater detail for the research questions concerning the achievement of CAP attributes in the online laboratory courses of our case study.

### Respondents' Demographics

A total of 139 students (98 males and 41 females) out of 273 from three different laboratory courses and semesters participated in the survey. The sample size gives a 95% confidence level and a 5.80% margin of error, which means the survey results are acceptable and representative of the engineering student population who took the courses. Figure 1 indicates that only 22.30% (31 out of 139 students) have attended physical laboratory at the university, while others only attended online courses because they were from the lower semesters and the online courses started in 2020.

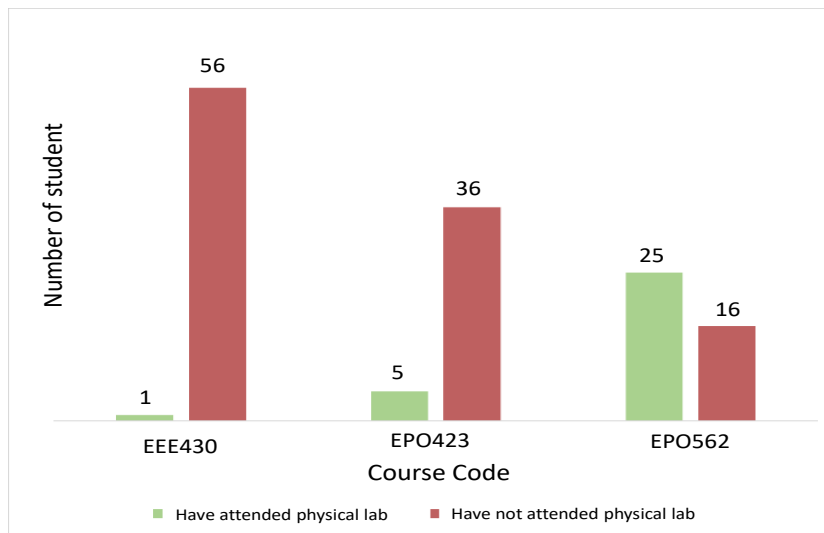


Figure 1. Respondents' demographic profiles data

### Reliability Test

The data were analyzed using SPSS version 28. The reliability statistics for the survey items are shown in Table 3. On average, the students responded positively to the thirteen items with good reliability, from 0.7 to 0.85 for Cronbach's Alpha (Taber, 2018). It confirms that all the questions have high internal consistency.

### Salient Outcomes from CAP analysis

For CAP analysis, data from the survey are considered ordinal categorical data since the survey questions were based on the level of agreement, from strongly agree to strongly



disagree (Chen & Wang, 2014). Hence, the data were analyzed by the median, lower and upper quartile of each item and the distribution of responses, i.e., the percentage that agrees or disagrees. Some responses are not uniformly distributed; hence, the median as central tendency and interquartile range (IQR) is used to measure the dispersion of data (Kostoulas, 2014).

Table 3  
*Reliability (Cronbach's Alpha) statistics*

Domains of Learning	Cronbach's Alpha
Cognitive*	0.815
Affective	0.726
Psychomotor	0.852

\*Note. Negatively worded items were reverse-scored

### Cognitive Learning

Table 4 shows the descriptive statistics for assessing students' cognitive learning perception. It shows the number of respondents, *n*, and the percentage of respondents who strongly agree, agree, is neutral, disagree, or strongly disagree with each question. The quartiles show that not more than 25% of the sample is below 2,

and not more than 25% is above 4. Thus, the data are concentrated in the center except for item I5, which is positively skewed.

Findings for the cognitive domain show that 41.00% agreed they could not produce a course study guide for future students (I1). Neutral is 30.94% and those who were sure they could produce a study guide are 28.06%. It suggests that most students (41.00% vs. 28.06%) may not be competent to independently organize knowledge and their learning process in the form of a personal course study guide. This suggestion is further strengthened by findings for I2 and I3, where for both questions, most students agreed that they are not competent to organize their tasks or relate to experiments. It could thus be concluded that the learning process delivered online was not effective. As for I4, more students think they could complete the experiment individually (35.25% vs. 30.93%); for I5, the majority could complete the group task.

Table 4  
*Descriptive statistics of cognitive learning*

Cognitive	Median	Q1	Q3	Strongly disagree <i>n</i> (%)	Disagree <i>n</i> (%)	Neutral <i>n</i> (%)	Agree <i>n</i> (%)	Strongly agree <i>n</i> (%)
I cannot produce a course study guide (compilation of topics, exercises, and learning activities) for future students. <b>(I1)</b>	3	2	4	4 (2.88)	35 (25.18)	43 (30.94)	47 (33.81)	10 (7.19)

Table 4 (Continue)

Cognitive	Median	Q1	Q3	Strongly disagree <i>n</i> (%)	Disagree <i>n</i> (%)	Neutral <i>n</i> (%)	Agree <i>n</i> (%)	Strongly agree <i>n</i> (%)
I cannot organize my tasks, apply appropriate methods and solve related problems to achieve the desired outputs (I2)	3	2	4	7 (5.04)	33 (23.74)	53 (38.13)	36 (25.90)	10 (7.19)
I cannot relate the online lab experiments with fundamental concepts and theories (I3)	3	2	4	6 (4.32)	31 (22.30)	49 (35.25)	40 (28.78)	13 (9.35)
I cannot complete the online lab independently (I4)	3	2	4	11 (7.91)	38 (27.34)	47 (33.81)	27 (19.42)	16 (11.51)
I cannot complete all the required group tasks effectively and timely (I5)	2	2	4	17 (12.23)	53 (38.13)	27 (19.42)	34 (24.46)	8 (5.76)

Our findings differ from the perceived opinion of academics (with a mean score of 3.78 out of 5) that cognitive learning can be attained in online courses based on the survey (Khidzir et al., 2016). It also contradicts the findings of Kawasaki et al. (2021) that cognitive learning was not affected in an online nursing course. Overall, the perceived cognitive learning was unsatisfactory for the online laboratory. An adequate performance should reveal a median score of at least 2 and below if most students disagreed/strongly disagreed that they could not do the tasks in I1 to I4. Hence, it can be said that some aspects of cognitive learning were lost in online labs. Factors that contributed to this should be identified and further investigated.

### Affective Learning

Table 5 shows the descriptive statistics for the items assessing affective learning, the number of respondents, *n*, and the percentage (%) of respondents who strongly agree, agree, are neutral, disagree, or strongly disagree with each question. Contrary to the results of the cognitive domain, responses for all four items are negatively skewed in the affective

domain, as seen in Table 6. Most respondents show agreement with all statements, i.e., I6 to I9. About 74% of the respondents agreed they were actively involved in the learning process (I6), whereas 84.17% agreed they could collaborate well with others in their lab group (I7). However, only 58.99% agreed they could communicate results and findings through reports and demonstrations. It indicates that the online laboratory courses provided space to interact with their peers or instructors, which helps the learning process. However, respondents who disagree or are neutral about these aspects of the online lab may be affected by internet connectivity and their motivation to learn in an online environment.

As for I9, surprisingly, 86.30% agreed with the statement, agreeing that they are aware of the safety requirements when working in a physical lab compared to an online lab, even though only 22.30% of the respondents had experienced being in a physical lab before the pandemic. It could be attributed to the explanation of safety by instructors or provided in the lab manual. In addition, those who may not have entered the lab due to the pandemic, i.e., semester 1 to semester 3 students, may have responded to this question based on their safety awareness in previous physical labs experienced in their secondary/diploma studies. These may be some factors that can be further investigated. Overall, the results of the affective domain reveal that the students have good attitudes and values. They could evaluate their own learning experiences quite well. It can be observed that this aspect of learning is preserved in an online setting. It can be supported by the findings of (Kawasaki et al., 2021) that affective learning in online labs is as effective as in face-to-face labs. In addition, it is shown that affective learning is not affected when students use digital resources compared to traditional textbooks (Horning, 2018).

Table 5  
*Descriptive statistics of affective learning*

Affective	Median	Q1	Q3	Strongly Disagree <i>n</i> (%)	Disagree <i>n</i> (%)	Neutral <i>n</i> (%)	Agree <i>n</i> (%)	Strongly Agree <i>n</i> (%)
I am actively involved in the learning process through the online lab (I6)	4	3	5	0 (0)	12 (8.63)	25 (17.99)	64 (46.04)	38 (27.34)
I can collaborate well with others in my group (I7)	4	4	5	0 (0)	5 (3.60)	17 (12.23)	49 (35.25)	68 (48.92)

Table 5 (Continue)

Affective	Median	Q1	Q3	Strongly Disagree n (%)	Disagree n (%)	Neutral n (%)	Agree n (%)	Strongly Agree n (%)
I can communicate my findings and results through reports and oral presentations (I8)	4	3	4	1 (0.72)	8 (5.76)	48 (34.53)	62 (44.60)	20 (14.39)
I am aware of the safety requirements when working in a physical lab compared to an online lab (I9)	4	4	5	2 (1.44)	5 (3.60)	12 (8.63)	64 (46.04)	56 (40.29)

**Psychomotor Learning**

Table 6 shows the descriptive statistics of psychomotor learning, and it portrays different types of distribution with an IQR score of 1. It means most of the answers are concentrated at the 'neutral.' As for the psychomotor domain, 65.47% of the students agreed/strongly agreed that they could perform the online lab experiments multiple times, unrestricted by laboratory space, rules, and safety concerns (I10). Response to (I11) showed that more than half of the samples could visualize the procedure to use the lab's equipment through the online lab video. It indicates that the delivery method, such as video demonstrations, instructor explanations, and lab manuals, have satisfactorily instilled students' knowledge and understanding of guided responses.

As for items I12 and I13, 42.45% indicated they could demonstrate the skills learned (I12) to others, whereas 34.53% agree/strongly agree they could operate actual equipment. However, approximately 42 to 45% of the students were neutral with the statement that they could demonstrate the physical/technical skills learned and operate the equipment confidently. The relevance of experience in the physical lab with the ability to demonstrate technical skills and operate actual equipment confidently is portrayed in the bar graphs in Figure 2.

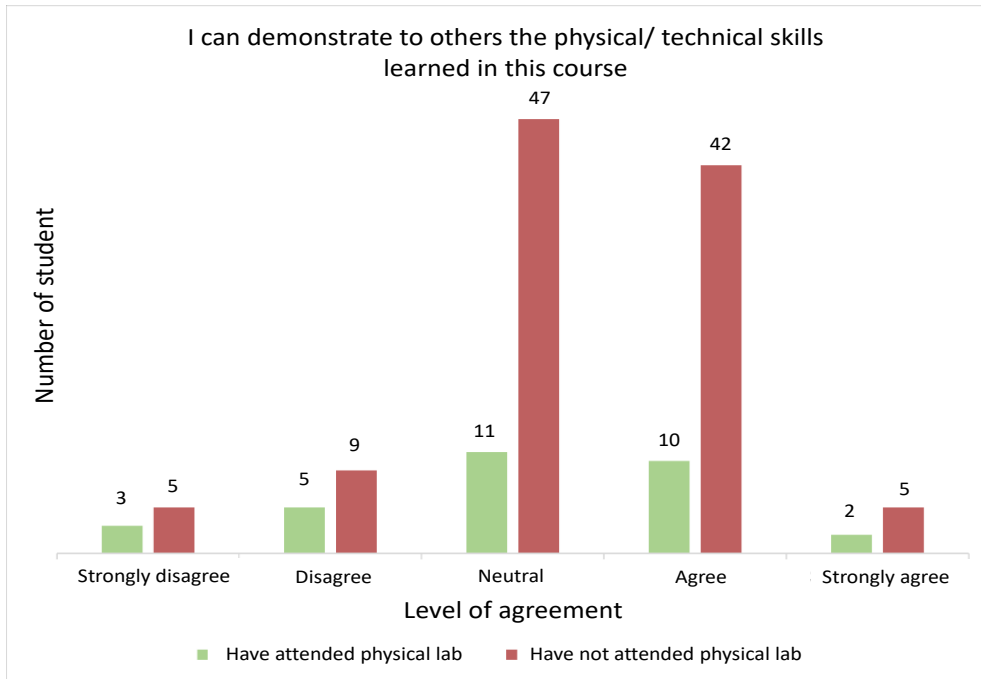
Figure 2(a) shows that 25.81% (8 out of 31 students) who have attended physical lab perceive that they could not demonstrate the skills they have learned. Figure 2(b) shows a similar trend where 29.03% (9 out of 31 students) with physical lab experience rate themselves as incapable of confidently operating actual equipment. It is probably based on their experience that they knew the difficulty of handling the actual equipment compared to

Table 6

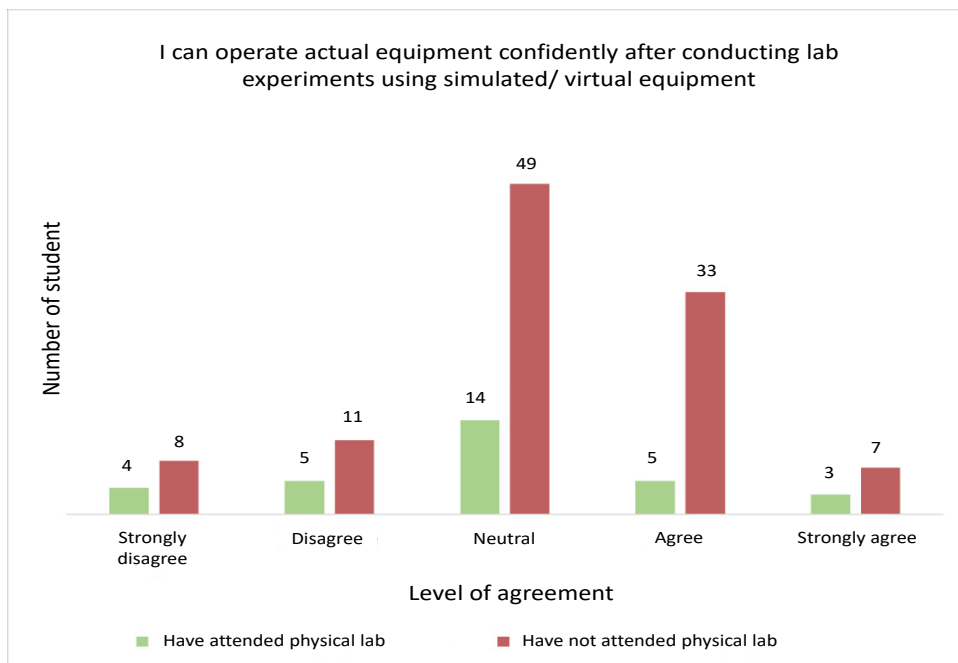
*Descriptive statistic of psychomotor learning*

Psychomotor	Median	Q1	Q3	Strongly Disagree <i>n</i> (%)	Disagree <i>n</i> (%)	Neutral <i>n</i> (%)	Agree <i>n</i> (%)	Strongly agree <i>n</i> (%)
I can perform the online lab experiments multiple times, unrestricted by laboratory space, rules, and safety concerns (I10)	4	3	4	3 (2.16)	5 (3.60)	40 (28.78)	62 (44.60)	29 (20.86)
I can visualize the procedure to use the lab's equipment through the online lab videos (I11)	3	3	4	3 (2.16)	20 (14.39)	49 (35.25)	50 (35.97)	17 (12.23)
I can demonstrate to others the physical/ technical skills learned in this course (I12)	3	3	4	8 (5.75)	14 (10.07)	58 (41.73)	52 (37.41)	7 (5.04)
I can operate actual equipment confidently after conducting online lab experiments using simulated/ virtual equipment (I13)	3	3	4	12 (8.63)	16 (11.51)	63 (45.32)	38 (27.34)	10 (7.19)

the virtual simulations. Taking the analysis a step further, we performed the Mann-Whitney U-test on item I13 to investigate if there is any significant difference between students who have and have not attended physical lab before. The Mann-Whitney U-test is chosen as the alternative to the independent t-test since, in this research, the Likert scale is considered ordinal data, as discussed earlier, Salient Outcomes from CAP analysis. Hence the suitable inferential statistic is the nonparametric Mann-Whitney U-test. The result is seen in Table 8.



(a)



(b)

Figure 2. Difference of perception between students who have and have not attended physical lab for items I12 (a) and I13 (b)

With a non-significant p-value of 0.186 ( $p > 0.05$ ) for the Mann-Whitney U-Test shown in Table 7, we can conclude that there is no statistically significant difference ( $p > 0.05$ ) between students who have or have not been in a physical lab before when it comes to their confidence in operating lab equipment after conducting online lab experiments using simulated/virtual equipment.

Table 7  
Mann-Whitney U-test

	Test Statistics <sup>a</sup>
	I can operate actual equipment confidently after conducting online lab experiments using simulated/virtual equipment
Mann-Whitney U	1428.500
Wilcoxon W	1924.500
Z	-1.321
Asymp. Sig. (2-tailed)	.186

a. Grouping Variable: Have or have not attended physical lab

In addition, as seen in Table 8, the mean rank for the group that has not attended physical lab is 72.27, while the mean rank for the group that has attended physical lab is 62.08. It illustrates that the scores between both groups tend to be similar, indicating that the confidence level in handling equipment after online simulations is independent of the student's physical lab experience.

Overall, those who indicated they could handle actual equipment were lower at 34.53% (48 out of 139 students) compared to those who were confident to demonstrate the skills (i.e., software/simulations) learned, which is much higher at 42.45% (59 out of 139 students). Furthermore, the simulation does not reflect real issues because symbols or icons of components do not emulate the real components in true behavior. Hence, the 42.45% who agree/strongly agree with I12 believe they could demonstrate to others that the physical/technical skills learned in the course were mostly software.

Table 9  
Rank of students who have and have not attended physical lab for item item I13

	Have or have not attended physical lab	N	Mean Rank	Sum of Ranks
I can operate actual equipment confidently after conducting online lab experiments using simulated/virtual equipment	No	108	72.27	7805.50
	Yes	31	62.08	1924.50
	Total	139		



The beauty of online courses is that students can perform experiments multiple times without restrictions. However, students cannot properly visualize the lab procedures without good video demonstrations or visualization ability. As for those who have not attended any physical lab, more than 40.00% were neutral on their ability to operate the equipment (I13) or demonstrate the physical skills (I12), as presented in Table 7, which could be because they had not been exposed to handling actual equipment. The hands-on aspect of the psychomotor domains suffers the most loss in an online lab, where only 34.53% of respondents indicated they could confidently handle actual equipment. This finding can be somewhat supported by the perceived opinion from academics that psychomotor skills may be the most poorly attained in online distance learning (Khidzir, 2016). Lewis (2014) also concurred that virtual labs could not provide students with actual hands-on experience. However, it is interesting to note that Kawasaki et al. (2021) stated that psychomotor learning in online labs is as effective in face-to-face settings for nursing students. Perhaps hands-on learning may not be ineffective in an online environment depending on the level of difficulty of the psychomotor skill that needs to be imparted and the complexity of the required equipment. It can be further explored and analyzed in future research.

## CONCLUSION

This research aims to measure and evaluate students' learning efficiency in electrical and electronics engineering online laboratory courses in the CAP learning domains. The findings indicate the advantages of teaching laboratory courses online, especially in the affective learning domain. Though conducted online, the laboratory courses seem capable of attracting students' enthusiasm for learning through interactivity, encouraging collaboration, and offering a safe environment by maximizing time and space flexibilities through simulated experiments. Hence, the affective learning domain is still preserved.

On the other hand, it was discovered that safety awareness and ethics are best instilled in a physical lab. The major disadvantage is that teaching laboratory courses online affects learning in the psychomotor domain. Students become unfamiliar with physical instruments and real devices, which may affect their confidence level when faced with the actual equipment in the future. Simulated experiments and video demonstrations could not help students attain hands-on skills effectively. So, transferable hands-on skills cannot be achieved. In addition, attributes in the cognitive domain are unattainable because of the limitation of the sample size of experienced students in the physical lab since only 22.30% (31 out of 139 students) have attended the physical lab before. The cognitive learning which was averagely attained can also be attributed to various factors such as the delivery methods of the instructors, the clarity of the video demonstrations, and lab manuals. Poor design and implementation of the delivery method could lead to the ineffective impartation of knowledge and understanding. It is good that further works should scrutinize and evaluate

online lab delivery methods and other contributing factors such as internet connectivity and student self-learning ability in an online environment.

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