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AJVAH
e-ISSN: 2735-1165
DOI: https://doi.org/10.53797/ajvah.v6i1.8.2025

The Correlation Between Students' Cognitive and Psychomotor Performance in an Embedded Systems Course in Electrical Engineering

Baharudin, Rohaiza[1*], Abbas, Mohd Hussaini[1], Rosli, Anis Diyana[1], Zanal, Asmalia[1], Abd Rahman, Mohammad Faizal[1] & Che Ani, Adi Izhar[1]

[1]Electrical Engineering Studies,
Universiti Teknologi MARA Cawangan Pulau Pinang
Permatang Pauh Branch, 13500 Seberang Prai, Penang, MALAYSIA

*Corresponding author email: rohaiza684@uitm.edu.my

Received 27 March 2025; Revision 13 May 2025 Accepted 20 May 2025; Available online 05 July 2025

Abstract: This study examines the relationship between students' performance in the cognitive and psychomotor domains within the context of Electrical Measurement (ESE122) for the Diploma in Electrical Engineering program. The research aims to assess how theoretical knowledge (cognitive domain) and practical skills (psychomotor domain) contribute to overall course outcomes in this embedded course. A total of 193 students participated in the study. The course assessment is composed of 70% cognitive domain and 30% psychomotor domain. Descriptive statistical analysis, including frequency counts and measures of central tendency, was employed to evaluate student performance. Additionally, Spearman's rank-order correlation was used to determine the association between cognitive and psychomotor scores. The findings indicate a positive correlation between the two domains, suggesting that students who excel in theoretical assessments tend to perform well in practical applications. These results highlight the importance of integrating hands-on learning with theoretical instruction to enhance student competency. The study provides insights for curriculum development, emphasizing a balanced approach to knowledge acquisition and skill application in engineering education.

Keywords: Cognitive, Psychomotor, Embedded Course, Course Outcome, Program Outcome

1. Introduction

The development of cognitive and psychomotor abilities is crucial in engineering education to produce well-rounded graduates who can satisfy industrial demands. The cognitive domain in electrical engineering involves knowledge acquisition, comprehension and critical thinking of a particular topic (Bhuyan, 2014; Yasmeen et al., 2019). While, psychomotor domain places more emphasis on practical skills, which allow students to apply theoretical ideas in real situations (Salim et al., 2012).

Integration of these two areas is emphasized in the Engineering Technology Accreditation Council's (ETAC) 2020 Manual, which also highlights the need for engineering programs to provide students the chance to succeed in both academic knowledge and practical skills. This approach aligns with industry standards, which emphasize the importance of fluidly transitioning from conceptual knowledge to practical application.

This study investigates how students' performance in the cognitive and psychomotor domains relates to one another, especially when an embedded course is involved. Embedded courses serve as an example course of the need for both domains, where conceptual mastery and operational skills work in tandem to achieve learning outcomes (Balid et al., 2012; Noor et al., 2020). The psychomotor and cognitive domains of Bloom's Taxonomy are used as guidelines for teaching and learning in embedded courses as in Table 1 (Bloom & Krathwohl, 1956).

Corresponding author: rohaiza684@uitm.edu.my
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Table 1: Bloom's Taxonomy levels for cognitive and psycomotor domain. (Hoque, 2016)

Domain	Level
Cognitive	The cognitive domain contains learning skills predominantly related to mental (thinking) processes. C1: Knowledge C2: Comprehension C3: Application C4: Analysis C5: Synthesis C6: Evaluation
Psychomotor	Psychomotor objectives are those specific to discreet physical functions, reflex actions and interpretive movements P1: Perception P2: Set P3: Guided Response P4: Mechanism P5: Complex Overt Response P6: Adaption P7: Origination

Only a small number of studies have examined the efficacy of embedded courses in non-electrical engineering programs to date (Ferris & Aziz, 2005; Mariyam & Riwayati, 2018; Zaghloul, 2001). Therefore, as the embedded course is handled differently at the university, a study on the cognitive, psychomotor, and affective domains of students' performance in electrical engineering courses is required.

Thus, this paper aims to assess students' performance based on the cognitive and psychomotor domain levels. Additionally, the analysis is performed to determine whether coursework assessments, which primarily focus on the psychomotor domain, correlate with the cognitive domain, as evaluated through tests and the final examination.

1.1 Description of the Courses

This study draw data from the course code ESE122, a core course of the electrical engineering diploma curriculum offered in the second semester at a public university. The Electrical Measurement course, introduces students to the foundational concepts and practical techniques essential in the field of electrical measurement.

This subject emphasizes understanding standard units, measurement accuracy, and error types, with a cognitive focus of 70% and a psychomotor emphasis of 30%. Students learn the principles and applications of various measuring instruments, including DC and AC meters, ohmmeters, and oscilloscopes, for accurate readings in different circuit types.

Course Outcomes (COs) are statements of objectives to be achieved by students at the end of a semester. Table 2 displays the list of COs and POs for this subject. Both CO1 and CO2 refer to the cognitive domain, while CO3 refers to the psychomotor domain.

Table 2: Course Outcome vs Program Outcome (ETAC)

Domain	CO	PO
Cognitive	**CO1:** Discuss basic concept and method of analysis in measuring instruments and transducers based on their working principles.	**PO1:** Apply knowledge of applied mathematics, applied science, engineering fundamentals and an engineering specialisation to wide practical procedures and practices.
Cognitive	**CO2:** Apply method of analysis in measuring instruments and transducers based on their working principles.	**PO2:** Identify and analyse well-defined engineering problem reaching substantiated conclusions using codified methods of analysis specific to their field of activity.
Psychomotor	**CO3:** Construct basic measuring circuit using simulation software and/or experimental setup.	**PO4:** Conduct investigations of well-defined problems; locate and search relevant codes and catalogues, conduct standard tests and measurements.

Additionally, the course covers bridge circuits, like the Wheatstone and Maxwell bridges, for precise resistance, capacitance, and inductance measurements, along with transducers that convert physical quantities into electrical signals. This combination of theoretical knowledge and hands-on skills prepares students to achieve reliable and accurate measurements in their future engineering endeavours.

The cognitive domain is easier to measure compared to the psychomotor domain. The Bloom's Taxonomy levels of the cognitive and psychomotor domains for each assessment are tabulated in Table 3. It is assessed through tests and the final examination, with allocations of 20% and 50% of the total score, respectively. Since this subject is in Semester 2, the highest level of the cognitive domain assessed is C4. For the psychomotor domain, the highest level assessed is P2, which accounts for 20% from lab exercises consisting of six experiments and 10% from a practical test.

Table 3: Bloom's Taxonomy levels for cognitive and psycomotor assessment

Domain	Level category	Level for Electrical Measurement
Cognitive	C1: Knowledge C2: Comprehension C3: Application C4: Analysis C5: Synthesis C6: Evaluation	Test: C1 – C2: 10% C3 – C4: 10% Final examination: C1 – C2: 60% C3 – C4: 40%
Psychomotor	P1: Perception P2: Set P3: Guided Response P4: Mechanism P5: Complex Overt Response P6: Adaption P7: Origination	Lab Exercise: P1 – P2: 20% Practical Test: P1 – P2: 10%

Table 4 presents the modules and corresponding chapters that link the psychomotor and cognitive elements. The learning process begins with students acquiring knowledge through lectures (cognitive), enabling them to perform laboratory work (psychomotor). This approach is designed to develop both cognitive understanding and practical skills. After completing all six modules, a laboratory test will be conducted to assess students' hands-on abilities. Both the laboratory work and test focus on evaluating their proficiency in conducting experiments, handling equipment, and collecting data.

Table 4: List of Laboratory Module

Chapter	Laboratory Module
DC and AC meters	Module 1: Ammeter Insertion Effect
	Module 2: Voltmeter Loading Effect
Cathode Ray Oscilloscope (CRO)	Module 3: Ossciloscope Application
	Module 4: Lissajous Patterns
Bridges	Module 5: Wheatstone Bridge
	Module 6: Bridge Controlled Circuit

1.2 Planning Stage for Cognitive and Psychomotor

1.2.1 Delivery Method

Lecture sessions serve as the delivery method for the cognitive domain. In three hours over the course of fourteen weeks, the lecturer covered the linked subjects as outlined in the syllabus. The laboratory session serves as the delivery technique for the psychomotor domains in the meantime. For seven weeks, it is held twice a week for two hours.

1.2.2 Assessment of the course

The evaluation of the cognitive domain consists of two tests and a final examination. Each test is conducted for approximately 1.5 hours, while the final examination lasts 3 hours. The final examination includes five questions with a total of 100 marks and is structured according to the percentage distribution for each cognitive level. Continuous assessments are conducted in Week 7 (Test 1) and Week 14 (Test 2).

Table 5: Percentage assessment for Cognitive and Psychomotor

Domain	Percentage
Test 1 & Test 2 (Cognitive)	20%
Practical Test (Psychomotor)	10%
Lab Exercises (6 Experiments) (Psychomotor)	20%
Final Examination (Cognitive)	50%
TOTAL	**100%**

For the psychomotor domain, continuous assessments are conducted for each experiment, evaluated according to the rubric presented in Table 5. The final assessment for the psychomotor domain is perform in week 13, referred to as the practical test, which covers experiments conducted throughout the semester. Each experiment and practical test is evaluated based on the student's individual performance and assessed by the instructor using specific rubrics for each psychomotor level, with the mark distribution detailed in Table 6.

Table 6: Rubric for Lab Exercise

Criteria	Sub-Attribute
Experimental/ Demonstration setup	**Handling Tools/Equipment** Ability to demonstrate a proper use of tools/equipment
	Conducting Experiment Ability to construct circuit/hardware
Output	**Output Response** Ability to obtain output response
	Output Validation Ability to perform data validation based on the measured result

2. Materials and Methods

Electrical Measurement is designed for Semester 2 of the Electrical Engineering diploma program at Universiti Teknologi MARA, Campus Permatang Pauh. The examination results of 193 students from three different semesters were used for data analysis.

2.1 Scoring guide

Tables 7 and 8 present the scoring guide used to categorize students' performance based on their cognitive and psychomotor domain achievements. There are five score ranges, with "Very Poor" representing the lowest performance and "Excellent" representing the highest. These performance levels allow for a structured evaluation of students' cognitive achievements.

Table 7. Scoring guide of percentage marks obtained for Cognitive Domain

Scoring guide	Range marks	
	Test	Final Exam
Very Poor	0 – 3.9	0 – 9.9
Poor	4 – 7.9	10 – 19.9
Fair	8 – 11.9	20 – 29.9
Good	12 – 15.9	30 – 39.9
Excellent	16 - 20	40 - 50

Table 8. Scoring guide of percentage marks obtained for Psychomotor Domain

Scoring guide	Range marks	
	Lab Exercise	Practical Test
Very Poor	0 - 3.9	0 - 1.9
Poor	4 - 7.9	2 - 3.9
Fair	8 - 11.9	4 - 5.9
Good	12 - 15.9	6 - 7.9
Excellent	16 - 20	8 - 10

2.2 Statistical Analysis

Data analysis in this study was performed using Microsoft Excel. The significance level, or α, for hypothesis testing in this study is set at 0.05. This threshold balances the possibility of Type I errors while retaining enough sensitivity to identify significant associations in the data, indicating a 5% chance of mistakenly rejecting the null hypothesis. Furthermore, Spearman's rank-order correlation coefficient was employed in the statistical analysis to determine the relationship between the performance of the students in each domain. The findings showed that students' performance in each area was positively correlated if the Spearman's rank-order was between $-1 \le r \le 1$; a strong negative correlation is represented by a value of -1, no correlation is represented by a value of 0, and a strong positive correlation is represented by a value of 1. The findings derived from Spearman's correlation coefficient ought to support one of the following theories:

H0: There is no correlation between cognitive and psychomotor domain which was obtained by the students.

H1: There is a correlation between cognitive and psychomotor domain which was obtained by the students.

3. Result and Discussion

3.1 Cognitive domain

The test and final exam scores were used to measure the cognitive domain's assessment. This is due to the fact that the cognitive domain includes knowledge, comprehension, application of theory, and analytical problem-solving skills. Questions for the test and final exam were developed using varying degrees of cognitive ability. Figure 1 shows the distribution of the student's accomplishments based on the scoring standards and grades received.

Table 9 presents the findings, showing that the majority of students (50.78%) achieved good marks in the test, scoring between 30 and 39, while 20.73% attained excellent marks. In the final examination, most students (33.16%) scored between 20 and 29, categorized as fair, with only 8.29% achieving excellent marks. A noticeable difference is observed between test and final examination performance, as students performed better in the test. This discrepancy may be attributed to the test being divided into two parts: Test 1, conducted in Week 6, and Test 2, in Week 13. Each test covered specific chapters, whereas the final examination assessed the entire syllabus.

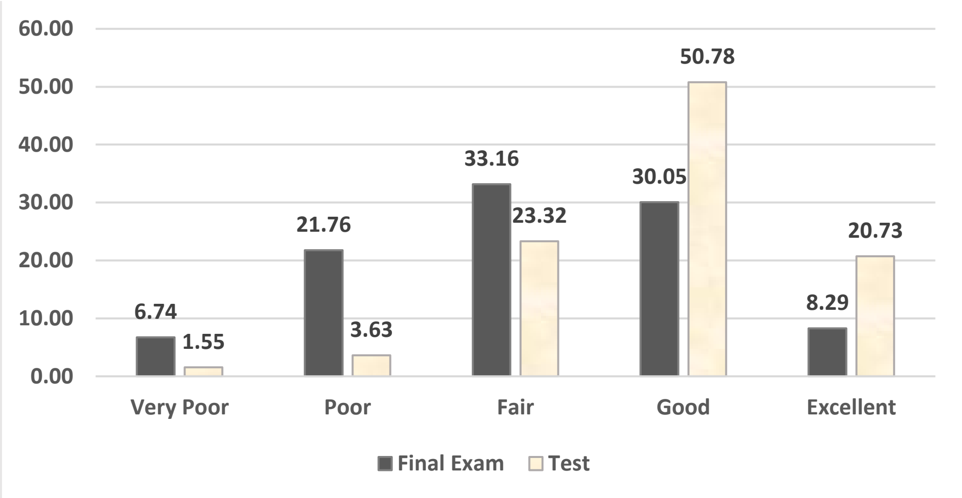

Fig 1: Cognitive domain attainment for test and final examination.

Table 9. Cognitive Domain attainment.

Scoring guide	Test		Final examination	
	Range marks	Percentage of students (%)	Range marks	Percentage of students (%)
Very Poor	0 – 3.9	1.55	0 – 9.9	6.74
Poor	4 – 7.9	3.63	10 – 19.9	21.76
Fair	8 – 11.9	23.32	20 – 29.9	33.16
Good	12 – 15.9	50.78	30 – 39.9	30.05
Excellent	16 - 20	20.73	40 - 50	8.29

3.2 Psychomotor domain

According to outcome-based education, one of the key learning objectives for the Electrical Engineering course is for students to be able to integrate theory and practice. Students should also be able to become proficient in carrying out experimental work in order to meet the requirements set forth by the Engineering Technology Accreditation Council (Mat Isa et al., 2020).

The written technical report was the sole instrument used in the past to evaluate laboratory proficiency. However, relying solely on the written report is insufficient to evaluate the students' proficiency in performing certain laboratory tasks, including handling the equipment, construction circuit and display the experiment according to the proper technique. In order to assess how well students demonstrated the laboratory activities, a practical skill assessment rubric was created.

The psychomotor domain is used to classify the evaluation of engineering students' physical behaviours during lab work (Salim et al., 2013). Students are graded using specific rubrics at various levels. The lab exercise is part of the psychomotor assessment, contributing 20% to the total final marks, while another 10% for psychomotor comes from the practical test. Fig. 2 shows the distribution of students' achievements based on the scoring criteria and marks earned. The majority of students achieved high marks in both the practical test and lab work components. Specifically, 82.38% of students attained an 'Excellent' rating in lab work, compared to 74.09% in the practical test.

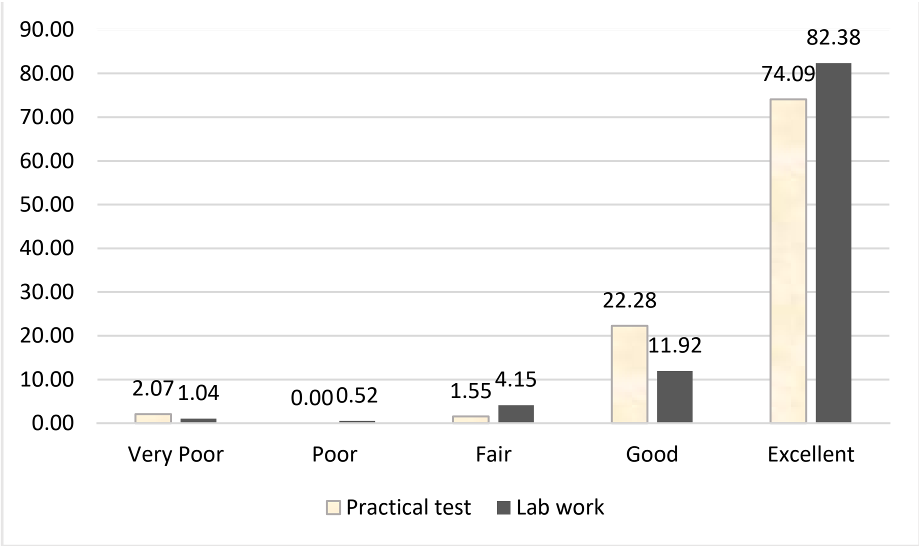

Fig. 2: Psychomotor domain attainment for lab work and practical test.

Table 10 presents the distribution of students' performance in the psychomotor domain, assessed through lab exercises and practical tests. The better performance in lab exercises compared to the practical test may be attributed to several factors. Lab work frequently gives students extra time and practical experience, which can improve their comprehension and skill proficiency. Furthermore, the practical test may be administered individually under time limits, making it more difficult for some students to perform at their best. In contrast, lab exercise is fully directed by guidance in the laboratory manual, and students can also request assistance from peers and instructors.

Table 10. Psychomotor Domain attainment.

Scoring guide	Lab Exercise		Practical Test	
	Range marks	Percentage of students (%)	Range marks	Percentage of students (%)
Very Poor	0 - 3.9	1.04	0 - 1.9	2.07
Poor	4 - 7.9	0.52	2 - 3.9	0.00
Fair	8 - 11.9	4.15	4 - 5.9	1.55
Good	12 - 15.9	11.92	6 - 7.9	22.28
Excellent	16 - 20	82.38	8 - 10	74.09

3.3 Correlation between cognitive and psychomotor

Fig. 3 shows the distribution of students' achievements based on the cognitive (70%) and psychomotor domain (30%). The cognitive domain analysis is based on a combination of test and final examination marks, while the psychomotor domain analysis is based on a combination of lab exercise and practical test marks. The majority of students achieved high marks in psychomotor (82.38%) attained excellent mark. But only 8.29% attained excellent mark for cognitive. The student score psychomotor compared to cognitive due to 20% (lab exercise) of the psychomotor is proper guided from lab manual and freely asking the instructor.

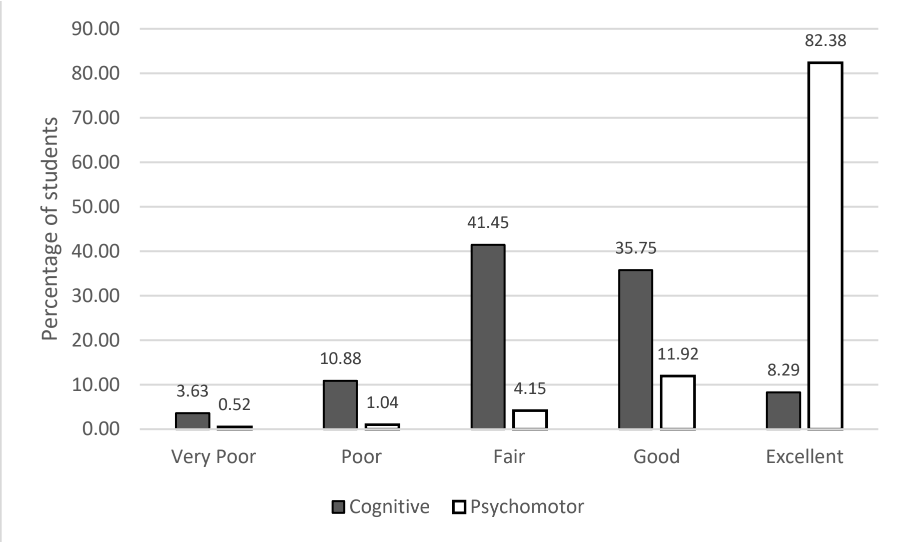

Fig 3: Distribution of student's achievement.

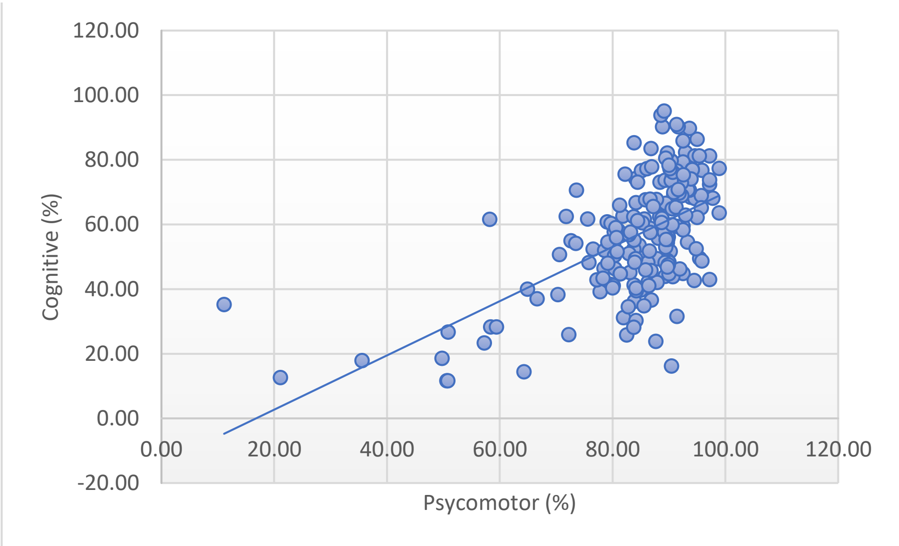

Fig. 4: Correlation Between Psychomotor and Cognitive Performance.

Fig. 4 shows a scatter plot representing the relationship between the psychomotor and cognitive domains. There appears to be a positive correlation between performance in these domains. As psychomotor scores increase, cognitive scores tend to increase as well. This positive trend suggests that students who perform well in psychomotor tasks also tend to achieve higher scores in cognitive tasks.

Table 11. Statistical analysis for ESE122

Domain	Evaluation	Mean	Standard Deviation	Correlation
Cognitive	2 Tests	56.9	17.63	0.58
	Final Examination			
Psychomotor	Lab exercise	85	12.10	
	Practical Test			

Table 11 provides descriptive statistics and correlation information for student performance for cognitive and psychomotor domain. The average (mean) score for the Cognitive domain is 56.9, indicating that students' performance on cognitive tests was comparatively moderate. In contrast, the Psychomotor domain has a higher average score of 85, suggesting that practical or hands-on tasks are performed more effectively than cognitive tasks.

The cognitive domain has a standard deviation of 17.63, showing more variability in students' scores, which may indicate that students' cognitive performance was more spread out with higher highs and lower lows. Meanwhile, the Psychomotor domain has a lower standard deviation of 12.10, suggesting that students' psychomotor scores were more consistent and clustered around the mean.

The strength of the correlation is considered an average positive correlation since the value falls within the range of $0.50 < r < 0.69$ (Ali & Al-Hameed, 2022). A moderately positive correlation of 0.58 exists between the cognitive and psychomotor domains. A correlation of 0.58 is classified as a moderate positive correlation, indicating that there is a significant but not substantial relationship between cognitive and psychomotor domains. This shows that students who perform well in cognitive may also excel in psychomotor skills, but the connection is not adequately enough to indicate constant relationship. The moderate correlation suggests that other variables may be influencing performance in each domain, such as practical experience from laboratory courses in previous semesters, guided laboratory manuals, or individual learning preferences.

While this moderate correlation indicates some association between cognitive and psychomotor skills, research suggests that several factors could influence performance in each domain. For instance, Balid et al. (2012) and Noor et al. (2020) found that students' ability to integrate theoretical knowledge and practical application can be influenced by curriculum design, which balances theoretical knowledge and operational skills. Similarly, factors like student experience and early exposure to practical tasks may explain why the correlation in this study is not stronger. Notably, the course under investigation is situated in the second semester of a six-semester study plan, which places students in the early phase of their academic development. In line with these studies, the moderate correlation could reflect the early stage of students' learning, as they may not yet have fully developed the technical fluency or confidence required to consistently apply theoretical knowledge in practical tasks.

Since the correlation is moderate, the teaching method should consider integrating activities that cover both cognitive understanding and practical application. An integrated learning technique involves following up theoretical instruction with hands-on activities that apply the concepts. For example, after teaching the bridge circuit, students can build and test circuits using simulation software in class to verify the theoretical concepts. The experiment should also include a pre-lab simulation that pairs theoretical knowledge with practical tasks. Assigning a pre-lab simulation using software (e.g., Multisim, Tinkercad) can help mirror the upcoming lab activity. After each lab session, students should complete a reflection activity where they link theoretical concepts to practical applications. This approach is expected to strengthen the connection between theoretical knowledge (cognitive domain) and practical skills (psychomotor domain), thereby reinforcing learning across both domains and addressing the limitations of the moderate correlation ($r = 0.58$) to promote more consistent and integrated learning outcomes.

4. CONCLUSION

This study focuses on the relationship between the psychomotor and cognitive domains in the Electrical Measurement course. Student performance was evaluated by examining both domains across three different cohorts. Assessing the psychomotor domain is more challenging compared to the cognitive domain. In this course, the cognitive domain is measured through tests and a final exam, while the psychomotor domain is assessed through lab exercises and practical tests. A rubric is essential for evaluating all psychomotor tasks. However, most students attain high scores in the psychomotor domain, as 20% of the lab exercises are guided by a lab manual and the instructor. The positive correlation between the psychomotor and cognitive domains suggests that proficiency in one area can enhance skills in the other. The findings indicate that incorporating psychomotor elements fosters cognitive achievement. Practical psychomotor tasks may improve comprehension of cognitive concepts, while a strong cognitive foundation can support the execution of psychomotor tasks in an embedded course. Moreover, students' performance in both cognitive and psychomotor domains should be well-balanced to align with industry requirements.

Future research could examine the impact of integrated teaching strategies, such as applied learning and reflective activities, designed to bridge the gap between cognitive and psychomotor skills. Additionally, investigating other embedded courses in electrical engineering and gathering qualitative feedback from students could provide further insights into how cognitive and psychomotor domains interact across different learning contexts.

Acknowledgement

The authors would like to express their gratitude to the Electrical Engineering Studies, Universiti Teknologi MARA, Cawangan Pulau Pinang, Malaysia for providing all the data needed for this research and for technical support.

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