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# Assessing Alternative Assessment for Psychomotor Domain in Engineering Education: Insights from a Qualitative Case Study Analysis

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## ABSTRACT

*The psychomotor domain of learning outcomes is required to equip the engineering graduate with the necessary attributes and skills. The measurement of psychomotor domain learning outcome is not straightforward compared to the cognitive domain of learning, which generally uses examination and tests to assess students' performance. The COVID-19 pandemic has posed a more significant challenge to assessment activities, and alternative remote assessment and teaching activities have been introduced since fieldwork and actual laboratory setups have been inaccessible. This paper evaluates the effectiveness of various implementations of course assessment under the psychomotor domain of learning for a civil engineering degree programme offered at Universiti Teknologi MARA Pulau Pinang. The efficacy of these alternative assessments in delivering the intended learning outcomes needs to be analysed for continual quality improvement (CQI). This study employed a qualitative case study approach, utilizing document analysis of the revised curriculum, syllabus for ODL, sample assessments, and related materials to examine the implementation of remote assessments in evaluating students' psychomotor skills. The findings indicate that the evaluated alternative remote assessments hardly assess the true attainment of student engineering practices and specialist knowledge in laboratory conduct during the pandemic. Despite various alternative assessments being identified, most can only develop student psychomotor skills up to level P2 (i.e. awareness). This study offers valuable insights for CQI, aiding in the enhancement of curriculum design to ensure alignment with the psychomotor learning outcomes essential for engineering education.*

***Keywords***: *alternative assessment, continual quality improvement, engineering education, laboratory, online distance learning, psychomotor domain of learning*

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## INTRODUCTION

Malaysian educational landscape was significantly transformed following the onset of the COVID-19 pandemic. Malaysian educators proactively reviewed and recalibrated teaching and learning activities and assessment methods (TLA) to align with the circumstances while pursuing the intended educational outcomes. The execution of TLA activities utilises synchronous and asynchronous methods, supporting various online learning and communication platforms. However, there are limitations and constraints of these existing platforms in facilitating remote assessments that can ensure a reliable and effective evaluation of student performances, particularly hands-on. The debates become louder when the TLA addresses psychomotor skills conducted virtually during the pandemic. Throughout the pandemic, programmes necessitating face-to-face assessments to evaluate psychomotor competencies, particularly in engineering, medical, culinary, dentistry, and other vocational programmes, encountered profound operational challenges. The impact of the pandemic on Malaysian students nationwide was investigated and reported by (Harun et al., 2021).

The need for developing students' knowledge, attitudes and practical skills in a specific field in the higher education curricula is highly accepted worldwide, including in the community, despite there being criticisms in various ways on the principle and implementation (Ferris & Aziz, 2005). Evaluating the students' psychomotor skills includes their ability to operate tools, machines, and computers, with face-to-face settings providing the most effective approach (Ramalingam et al., 2014). Nonetheless, pandemic-related restrictions on physical settings created significant challenges for TLA, which focused on developing students' practical skills. For instance, dentistry education struggled to fulfil the psychomotor components in the curriculum, representing 45% to 50% of the total student learning time (SLT) comprising clinical and practical activities (Fatah et al., 2021). The tourism and hospitality programmes faced challenges as students lacked practical experience due to widespread hotel and resort closures during the pandemic. The conduct of these programmes posed a substantial issue as Work-based learning (WBL) constituted 25% to 90% of the curriculums (Schleicher, 2020). In addition, science programme students could not conduct experiments in physics, chemical, and biological laboratories, assessing specific tools and instruments in a laboratory setting (Gamage et al., 2020). Similarly, the exposure of engineering students to operating laboratory instruments and machinery for experiments and investigations was interrupted during the pandemic. Engineering students' perceptions of their practical skill development based on Simpson's Model were studied (Chiew et al., 2022; Isa et al., 2020; Isa et al., 2024).

In the psychomotor domain, engineering students can show proficiency in conducting experiments, coordinating motor skills in laboratory settings, handling tools and machinery, etc., in laboratory courses. A robust and effective assessment approach is essential to capture true learning outcomes accurately. However, the effectiveness of virtual alternative assessments for the psychomotor domain in engineering education, especially in laboratory courses, remains uncertain. Misalignment in assessments may misinterpret students' achievement of learning outcomes, impacting the accuracy of graduates' skill profiles. Therefore, this paper aims to evaluate the relevancy and suitability of alternative assessments in laboratory courses addressing the psychomotor domain for an engineering programme. This study seeks to critically analyse the effectiveness of alternative assessments in delivering intended learning outcomes for Continual Quality Improvement (CQI) of the programme. This study also aims to answer several research questions:

1. How are the remote assessments of students' psychomotor skills conducted in an engineering programme?
2. Do the remote assessments effectively assess student's psychomotor skill attainment?

## LITERATURE REVIEW

### Psychomotor Domain in Assessing Students Learning

Assessment is vital in the learning cycle, and it is widely conducted to measure the student's learning development through three learning domains: cognitive, affective, and psychomotor. Initially developed by Benjamin Bloom in 1956 and revised in 2001 by Anderson and Krathwohl, the cognitive domain is related to the ability of students to utilise the knowledge and cognitive thinking process. Hence, the assessments commonly performed to evaluate students' cognitive learning domain include writing examinations, quizzes, and project-based assessments (Ramalingam et al., 2014). The affective domain, introduced by Krathwohl in 1964, measures students' abilities related to emotion, feeling, behaviour, and attitudes. The assessments that could measure the affective learning domain are presentation, debate, group discussion, and group work (Ramalingam et al., 2014). The psychomotor learning domain proposed by three different researchers, Simpson in 1972, Dave in 1970 and Harrow in 1972, is related to the ability of students to coordinate and perform motor skills. Measurement of students' learning in the psychomotor learning domain is commonly conducted through activities such as experimental work in the laboratory, culinary in the kitchen, and physical activities such as performing art and on-site activities.

The psychomotor learning domain generally focuses on developing the individual motor skills required for engineering practice. Psychomotor skills are measured in speed, precision, procedure, or technique execution (Mohd Yusoff et al., 2011). The development of the psychomotor learning domain began when Simpson (1972) noted that the Bloom and Krathwohl Model was insufficient. This inadequacy was especially noticeable in classifying educational objectives linked to psychomotor skills across different fields, including industrial practices, physical education, home economics, and agriculture. The classification for psychomotor skills was improved with seven distinct learning levels: perception, set, guided response, mechanism, complex overt response, adaptation, and origination. This refinement helps to understand better and assess the progression of skills in this domain.

Unlike the Simpson psychomotor learning domain, Dave (1970) and Harrow (1972) introduced five and six psychomotor learning domains, respectively. Table 1 compares levels of learning for Simpson, Dave and Harrow Models. Simpson's model is suggested for adult development, and Harrow's is suitable for developing physical fitness, agility, and control of sensor motors (Alobaidi, 2020). In the technical or vocational programme, evaluating students' psychomotor skills in handling specific tools machinery, and conducting experiments or hands-on activities is vital. Many technologies are invented to accelerate work, and the technology nowadays is advanced and shifting dynamically; hence, graduates from the technical or vocational programme are expected to master the psychomotor skills in handling the tools and machinery related to their key area and conducting work correctly. In Malaysian engineering programmes, the students' psychomotor skills are commonly assessed by adopting Simpson's psychomotor learning domain, as recommended by the Malaysian Qualifications Framework.

**Table 1: Comparison of Proposed Psychomotor Learning Domain Model**

| Simpson (1972) | (Dave, 1970) | (Harrow, 1972) |
|---|---|---|
| Perception | Imitation | Reflex movements |
| Set | Manipulation | Fundamental movement |
| Guided Response | Precision | Perceptual abilities |
| Mechanism | Articulation | Physical abilities |
| Complex Overt Response | Naturalisation | Skilled movement |
| Adaptation | | Non-Disclosure communication |
| Origination | | |

### Conducting Laboratory in Remote Setting

Various studies have documented the remote assessments employed during the COVID-19 pandemic, highlighting their effectiveness and the challenges educators and students face. Nolan et al. (2021) discussed how pharmacy schools modified their summative skills-based assessments to accommodate remote learning, emphasising the need for innovative assessment strategies to effectively evaluate students' practical skills despite the lack of physical presence. Similarly, Mayuze (2023) noted the difficulties in assessing psychomotor skills through online platforms, indicating that traditional methods were often inadequate for remote learning environments. Many studies highlighted the inherent limitations of online assessments in capturing the hands-on competencies required in engineering education. For example, Isa et al. pointed out that the transition to Open and Distance Learning (ODL) created significant barriers to assessing students' psychomotor skills, as the lack of direct supervision and interaction hindered effective evaluation (Isa et al., 2024). Furthermore, Rahim et al. (2023) compared face-to-face and online assessments in a water engineering laboratory, finding that the remote format often led to a decline in students' performance due to the absence of practical engagement. However, in another study, students exhibited improvements in their psychomotor skills during remote learning despite the challenges, indicating that some level of skill attainment was still achievable (Kabir et al., 2023). While various innovative assessment methods were employed, the effectiveness of these approaches varied, and concerns regarding the reliability of assessments persisted. The attainment of psychomotor skills, as framed by the Simpson model, demonstrated that while obstacles existed, opportunities for skill development remained, albeit in a modified format.

## METHODOLOGY

### Research Design

This study employs a qualitative case study approach, particularly document analysis, to examine the implementation of remote assessment in assessing the students' psychomotor skills during the pandemic. This approach uses multiple data sources to explore experiences within the context, providing a comprehensive view rather than a single perspective. The reviewed documents were the official syllabus documents for the laboratory courses, the revised curriculum documents for ODL, and the records of sample assessments given to the students. It aims to identify and followed by examine alternative assessment methods used in various laboratory courses during the pandemic. Implementations of remote assessments for five laboratory courses in the Bachelor of Civil Engineering (Infrastructure) programme offered at the School of Civil Engineering, Universiti Teknologi MARA Pulau Pinang, were reviewed. These laboratory courses, namely, Engineering Geology Laboratory, Geotechnical Laboratory, Highway and Traffic Laboratory, Environmental Laboratory, and Mechanical and Electrical Laboratory, were designed in the curriculum to develop students' psychomotor skills. The data was collected from the March - July 2020 semester, the first semester of ODL implementation during the pandemic. The efficacy of the alternative remote assessments in the chosen laboratory courses was evaluated based on course files, especially related to psychomotor skill attainment. Alternative remote assessments such as online test/quiz, online interview, home-based experiment, open-ended mini-projects and video presentation implemented in the chosen laboratory courses were evaluated. The school's top management appointed a group of internal educational and evaluation experts to review and assess these documents.

### Instrumentation

A document analysis research instrument was employed in this study using a systematic procedure to examine and evaluate the document, either imprinted or in electronic form. The relevant documents were reviewed and assessed to develop empirical knowledge in the focus area (Bowen, 2009; Chinedu & Wan Mohamed, 2017). The school provides all the documents for the chosen laboratory courses to ensure the focus area's authenticity, credibility, and accuracy. Different types of

documents were needed not only to help in the 'data triangulation' to develop the trustworthiness of the research but also to examine the research problem from different angles (Nightingale, 2020; Salkind, 2010).

The reviewed documents were the official syllabus documents for the laboratory courses, the revised curriculum documents for ODL, and the records of sample assessments given to the students. The document analysis process involved skimming, reading, and interpreting the documents. Triangulation on the official syllabus for the laboratory courses, the course learning outcomes, the course contents, teaching and learning activities, and the assessments were made.

## Data Analysis

Data from five laboratory courses were examined to evaluate the effectiveness of remote assessments during the pandemic. The analysis focused on alignment with programme outcomes and course learning outcomes and ensured coverage of the relevant knowledge profile (WK), complex engineering problems (WP), and complex engineering activities (EA). The suitability of the remote assessment used in all the laboratory courses was evaluated according to three performance criteria as follows:

i. Does the alternative method carry the knowledge that is relevant to the course?
ii. Are the alternative assessment activities suitable for attaining the intended course learning outcomes?
iii. Does the alternative assessment measure the course learning outcomes towards attaining the actual programme outcome (using constructive alignment)?

These performance criteria were developed with a 5-point scale and descriptors, as shown in Table 2.

**Table 2: Performance Criteria, Point Scale and Descriptors Used in Evaluating Remote Assessment for All Laboratory Courses**

| **Performance Criteria** | **Performance Level** | | | | |
|---|---|---|---|---|---|
| | **5:Very Much Relevant** | **4:Much Relevant** | **3:Quite Relevant** | **2:Less Relevant** | **1:Not Relevant** |
| Does the alternative method carry the knowledge that is relevant to the course?<br><br>(Fundamental Knowledge (WK3), Specialist Knowledge (WK4), Engineering Design (WK5), Research Literature (WK8) | The alternative assessment allows students to apply all relevant knowledge to the course to design a procedure or protocol to be carried out in the laboratory experiment. | The alternative assessment allows students to apply most of the relevant knowledge to the course to design a procedure or protocol to be carried out in the laboratory experiment. | The alternative assessment allows students to apply some relevant knowledge relevant to the course to design a procedure or protocol to be carried out in the laboratory experiment. | The alternative assessment allows students to apply less relevant knowledge to the course to design a procedure or protocol to be carried out in the laboratory experiment. | The alternative assessment shows that students apply the irrelevant knowledge of the course to design a procedure or protocol to be carried out in the laboratory experiment. |
| **Performance Criteria** | **5:Very Much Suitable** | **4:Much Suitable** | **3:Quite Suitable** | **2:Less Suitable** | **1: Not Suitable** |
| Are the alternative assessment activities suitable for attaining the | The alternative assessment is very suitable based on excellent student | The alternative assessment is much more suitable based on good student | The alternative assessment is quite suitable (acceptable) based on some student | The alternative assessments are less suitable based on minimal student | The alternative assessments are not suitable due to the lack of student involvement in |

| | | | | | |
|---|---|---|---|---|---|
| intended course learning outcomes?<br><br>Based on the conduct, interpretation, and presentation of the laboratory results | involvement in laboratory experiment conduct, interpretation, and presentation of the laboratory results. Thus, all intended course learning outcomes are measured effectively towards true attainment. | involvement in laboratory experiment conduct, interpretation, and presentation of the laboratory results. Thus, all intended course learning outcomes are measured directly towards true attainment. | involvement in laboratory experiment conduct, interpretation, and presentation of the laboratory results. Thus, some intended course learning outcomes are measured directly towards true attainment. | involvement in laboratory experiment conduct, interpretation, and presentation of the laboratory results. Thus, most of the intended course learning outcomes are less effectively measured, resulting in untrue attainment. | laboratory experiments and the interpretation and presentation of laboratory results. Thus, not all the intended learning outcomes are measured directly, resulting in untrue attainment. |
| **Performance Criteria** | **5:Well-Measured** | **4:Able to Measure** | **3:Able to moderately Measure** | **2:Less Measured** | **1: Not Able to Measure** |
| Does the alternative assessment measure the course learning outcomes towards the attainment of the actual programme outcome (using constructive alignment)? | Constructive alignment shows that the alternative assessment directly measures the course learning outcomes; thus, the direct and true attainment of the programme outcome is evident. | The constructive alignment shows very few mismatches; thus, the alternative assessment gives acceptable measures of the course learning outcomes; thus, direct and true attainment of the programme outcome is evident. | The constructive alignment shows few mismatches; thus, the alternative assessment shows less measurement of the course learning outcomes, resulting in untrue attainment of the programme outcome. | Constructive alignment shows some mismatches; thus, the alternative assessment shows less measurement of the course learning outcomes, resulting in untrue attainment of the programme outcome. | Constructive alignment shows that the alternative assessment does not measure the course learning outcomes, thus resulting in untrue attainment of the programme outcomes. |

## RESULTS AND DISCUSSION

This section evaluates alternative assessments implemented for laboratory courses in the Bachelor of Civil Engineering (Infrastructure) programme during ODL. The evaluation for each alternative assessment of the five (5) laboratory courses was based on three primary criteria: Criteria 1: Relevant Knowledge Profiles to the course, Criteria 2: Suitability of the alternative assessment to attain the intended course learning outcomes and Criteria 3: Assessments capturing the course learning outcomes towards the attainment of the actual programme outcome (PO). PO4 (Experiments, Research, Investigation) and PO5 (Technical Competency / Modern Tool Usage) were used as indicators of psychomotor competency and reflected in the knowledge profiles WK4 (specialist knowledge) and WK6 (engineering practice).

### Types of Alternative Assessments during ODL

Table 3 summarises the assessment methods used in the laboratory courses before and during ODL to assess students' cognitive, psychomotor and affective skills. It is noted that assessment methods such as laboratory reports, practical tests, and online tests were consistently used in the laboratory courses before and during the pandemic. Due to restrictions in physical operation, students learned engineering principles and laboratory setups online, with laboratory briefings and

demonstrations conducted virtually. Instructors provided experimental data after the laboratory demonstration so that students could prepare their laboratory reports. Practical tests and written exams were also conducted online, replacing traditional individual assessments in class. Other alternative assessments include open-ended mini-projects, video presentations demonstrating laboratory methods, online interviews to verify students' understanding, and recorded home-based laboratory experiments for selected tasks.

The alternative assessment tools, including lab reports, practical tests, online tests, video presentations, online interviews, and home-based experiments, targeted various learning domains and outcomes. Lab reports primarily assessed the communication skills emphasising affective domains. Online tests were concentrated on the cognitive domain, evaluating students' understanding, problem analysis, and experimental design or procedures. Meanwhile, practical tests, video presentations, online interviews, and home-based experiments focused on the psychomotor domain, predominantly focused on the psychomotor domain, emphasizing experimental investigation and tool application aligned with specific course outcomes and performance objectives.

**Table 3: Assessment Methods Used in Laboratory Courses During ODL**

| Laboratory Courses | Assessments | | | | | | |
|---|---|---|---|---|---|---|---|
| | A1* | A2 | A3 | A4* | A5* | A6 | A7 |
| CEG451 Engineering Geology | √ | | √ | √ | √ | | |
| CEG453 Geotechnical Laboratory | √ | | | √ | √ | | |
| CEG552 Highway Engineering | √ | | | √ | √ | | √ |
| CEM472 Mechanical & Electrical Engineering | √ | √ | √ | √ | √ | | √ |
| CEW545 Environmental Laboratory | √ | | √ | √ | √ | √ | √ |

Note: * indicate assessment similar to practice before and during the pandemic. Assessments A1(laboratory report), A2(project), A3(video presentation), A4(practical test), A5(online lab test/quiz), A6(online interview) and A7(home- based laboratory demonstration).

## Criteria 1: Relevant Knowledge Profiles to the Course

Table 4 summarises the evaluation of the relevance of alternative assessments in developing essential knowledge profiles for all laboratory courses during ODL. The evaluation was based on the knowledge profiles recommended in the EAC Standard 2020 published by the Malaysian Engineering Accreditation Council. Generally, the alternative assessments such as online tests or quizzes have effectively supported the students in gaining knowledge profiles in natural science (WK1), mathematics (WK2) and engineering fundamentals (WK3). Questions regarding specialised engineering matters also relevantly address specialist knowledge (WK4).

Other assessments, such as proposals of laboratory methodology and home-based experiments, are more relevant for engineering design (WK5) and engineering practice (WK6), respectively. Specifically, the students used WK5 to design experiments for a given open problem, as presented in their proposal. The students practised when they planned, arranged, and practised several experiments at home with appropriate tools. Even though creative ideas from the lecturer engage their students in developing knowledge profiles, these ODL activities hardly provide students with actual engineering practices (WK6) and specialist knowledge (WK4) in handling laboratory equipment. This study also identifies the absence of the ability to observe the actual response of the experiments, such as determining the properties and behaviour of structures or materials or determining chemical reactions in the conducted alternative activities during the pandemic, contributing to the lack of psychomotor domain assessment effectiveness.

**Table 4: Evaluation Details for Criteria 1**

| Lab Course | Designated WKs | Knowledge Profiles- Does the alternative method carry the knowledge that is relevant to the course? | Evaluation |
|---|---|---|---|
| CEG451 Engineering Geology | WK1-WK4 (PO1)<br>WK8 (PO4) | The alternative assessment allows students to apply most of the relevant knowledge:<br>The **online test (A5)** that mapped to PO1 reflects **WK1-4** relevantly.<br>The **practical test (A4)** that mapped to PO4 has an inadequate demonstration of **WK8**. | 4<br>(Much relevant) |
| CEG453 Geotechnical Laboratory | WK1-WK4 (PO2)<br>WK6 (PO5) | The alternative assessment allows students to apply a few of the relevant knowledge:<br>The **online test (A5)** that mapped to PO2 reflects **WK1-4** relevantly.<br>The **practical test (A4)** and **technical report (A1)** that mapped to PO5 have shown inadequate practice/ hands-on element **WK6**. | 3<br>(Quite relevant) |
| CEG552 Highway & Traffic Engineering | WK5 (PO3)<br>WK6 (PO5) | The alternative assessment allows students to apply most of the relevant knowledge:<br>The **online test (A5)** that mapped to PO3 reflects less **WK5**.<br>The **home-based experiments (A7)** that mapped to PO5 reflects **WK6** relevantly.<br>The **practical test (A4)** that mapped to PO5 has shown some hands-on elements of **WK6**. | 4<br>(Much relevant) |
| CEM472 Mechanical & Electrical Engineering | PO1<br>(WK1-4)<br>PO5<br>(WK6) | The alternative assessment allows students to apply most of the relevant knowledge:<br>The **online test (A5)** that mapped to PO1 reflects **WK1-4** relevantly.<br>The **practical test (A4)** that mapped to PO5 has shown some hands-on elements of **WK6**. | 4<br>(Much relevant) |
| CEW545 Environmental Laboratory | PO2<br>(WK1-4)<br>PO5<br>(WK6) | The alternative assessment allows students to apply most of the relevant knowledge:<br>The **online test (A5)** that mapped to PO2 reflects **WK1-4** relevantly.<br>The **practical test (A4)** that mapped to PO5 has shown some hands-on elements of **WK6**. | 4<br>(Much relevant) |

Note: Knowledge profiles WKs are natural science (WK1), mathematics (WK2), engineering fundamentals (WK3), specialist knowledge (WK4), engineering design (WK5) and engineering practice (WK6), and research literature (WK8). Also, refer to the types of assessments in Table 3.

## Criteria 2: Suitability of the Alternative Assessment Activities to Attain the Intended Course Learning Outcomes

Table 5 shows the evaluation remarks for Criteria 2 in determining the suitability of the alternative learning activities in attaining the intended course learning outcomes. Each laboratory course is mapped with the three-course outcomes that emphasise the cognitive, affective, and psychomotor domains at different levels of learning. Alternative learning activities are generally online lectures, laboratory demonstrations, home-based laboratories, and laboratory experiment proposals. These activities are suitable for obtaining learning outcomes associated with cognitive skills such as applying engineering knowledge, data analysis, design, and proposing solutions to engineering problems.

**Table 5: Evaluation Details for Criteria 2**

| Lab Course | Development of the intended learning outcomes<br>Course Outcomes (CO) and its mapping to Programme Outcomes (PO), Taxonomy Domain, and level of learning | Evaluation |
|---|---|---|
| CEG451 Engineering Geology | CO1- Acquire principles of engineering geology as applied to civil engineering and infrastructure works. (PO1, C4) | 3<br>(Quite Suitable) |

| | | |
|---|---|---|
| | CO2- Integrate the knowledge of geologic fundamentals to distinguish rock behaviour and its engineering characteristics for civil engineering and infrastructure works via laboratory tests. (PO4, P4)<br>CO3- Present engineering geology works through written reports. (PO10, A4)<br>Evaluation Remarks**:** The alternative assessments effectively address CO1, partially for CO3 and less effective for CO2. They are likely to develop students' cognitive skills C4 (i.e. analysis), psychomotor skills P2 (i.e. awareness, readiness to act) and affective skills A4 (i.e. compare, relate). | |
| CEG453 Geotechnical Laboratory | CO1- Apply knowledge of soil mechanics on a standard laboratory soil test and analyse data obtained from lab sessions (PO2, C4)<br>CO2- Conduct a laboratory test and produce technical reports related to the basic physical and mechanical properties of soils. (PO5, P5)<br>CO3- Conduct experiments effectively as an individual and as a member of a team (PO9, A4)<br>Evaluation Remarks: The alternative assessments effectively address CO1 but are less effective for CO2 and CO3. They are likely to develop students' cognitive skills C4 (i.e. analysis), psychomotor skills P2 (i.e. awareness, readiness to act) and affective skills A3 (i.e. propose, share, appreciate). | 3<br>(Quite Suitable) |
| CEG552 Highway & Traffic Engineering | CO1**-** Analyse, formulate and/or design professional solutions for the problems related to highway and traffic engineering (PO3, C4)<br>CO2- Conduct laboratory tests (PO5, P4)<br>CO3- Present laboratory findings (PO10, A4)<br>Evaluation Remarks: The alternative assessments effectively address CO1, partially for CO3 and less effective for CO2. They are likely to develop students' cognitive skills C4 (i.e. analysis), psychomotor skills P2 (i.e. awareness, readiness to act) and affective skills A3 (i.e. propose, share, appreciate). | 3<br>(Quite Suitable) |
| CEM472 Mechanical & Electrical Engineering | CO1- Appraise the knowledge and propose alternatives according to the concepts and theories of mechanical and electrical systems in the building. (PO1, C4)<br>CO2 -Conduct the laboratory session (PO5, P4)<br>CO3- Present laboratory findings. (PO10, A4)<br>Evaluation Remarks: **Alternative assessments effectively address CO1, partially** for CO3 and less effective for CO2 due to safety concerns. They are likely to develop students' cognitive skills C4 (i.e. analysis), psychomotor skills P4 (i.e. operate and construct model) and affective skills A3 (i.e. propose, share, appreciate). | 3<br>(Quite Suitable) |
| CEW545 Environmental Laboratory | CO1- Organise and conduct laboratory experiments to establish environmental-related parameters. (PO5, P5)<br>CO2- Analyse data of the experimental work with the environmental quality standards and provide solutions to the environmental engineering problems. (PO2, C4)<br>CO3**-** Conduct and perform experiments effectively as an individual and as a member of a team. (PO9, A4)<br>Evaluation Remarks: The alternative assessments effectively address CO2 but are less effective for CO1 and CO2. They are likely to develop students' cognitive skills C4 (i.e. analysis), psychomotor skills P3 (i.e. imitation) and affective skills A3 (i.e. propose, share, and appreciate). | 3<br>(Quite Suitable) |

In Engineering Geology (CEG451), online tests were effectively used to address theoretical outcomes (CO1), allowing students to acquire foundational knowledge in engineering geology concepts. However, CO2, which required the application of geological knowledge in laboratory settings, was less effectively met. Although students engaged in theoretical exercises, such as proposing laboratory procedures and suggesting rock slope mitigation strategies, the absence of physical laboratory experience limited the depth of practical understanding. Furthermore, CO3, which focused on presenting geological findings, was only partially realised, as students' laboratory skills were not fully developed. These findings indicate that while alternative assessments fostered cognitive skills (C4 – Analysis) and affective engagement (A4 – Compare; Relate), there was an evident gap in the psychomotor skill development necessary for real laboratory work (P2 – Awareness; Readiness to Act).

In the Geotechnical Laboratory (CEG453), students engaged in data analysis and procedure design based on lecturer-provided experimental data, which successfully developed CO1. Meanwhile, Highway and Traffic Engineering (CEG552) adopted a practical approach, wherein students analysed local pavement conditions and successfully addressed CO1. However, CO2 and CO3, focusing on direct laboratory engagement and teamwork or presenting laboratory findings, were inadequately addressed in the absence of physical lab sessions. Although alternative assessments encouraged cognitive analysis (C4) and promoted awareness and readiness in psychomotor skills (P2), the lack of real-time collaboration in laboratory settings hindered the development of essential teamwork and hands-on competencies. Thus, while cognitive outcomes were moderately achieved, the overall effectiveness was limited by the inability to provide practical laboratory experience.

In Mechanical and Electrical Engineering (CEM472), students conducted home-based experiments to study artificial lighting and develop sustainable models, meeting CO1 through cognitive engagement supported with online tests. These adaptations provided some psychomotor development (P4) as students engaged in model construction, though safety concerns with electrical work were noted. Despite these efforts, the lack of real laboratory infrastructure limited the authenticity of experimental conduct, particularly in CO2 and CO3, which involved the conduct of laboratory sessions and result presentations. The findings suggest that home-based assessments facilitated cognitive and affective skills (A3) to some extent but were less effective for developing robust practical skills due to safety constraints.

Lastly, Environmental Laboratory (CEW545) incorporated at-home experiments where students used improvised materials and video presentations, moderately achieving CO1 and CO3. This approach also facilitated cognitive analysis (C4) through data analysis and provided solutions for CO2. Although students demonstrated creativity and engagement, the lack of professional lab tools limited the authenticity of the experimental process, which offers basic psychomotor imitation (P3).

Overall, the alternative assessments demonstrated effectiveness in fostering cognitive and affective skills, particularly in analytical and collaborative aspects. However, the absence of real laboratory environments posed significant challenges in achieving practical, psychomotor-based learning outcomes, which are critical for comprehensive skill development in engineering education. This suggests that while cognitive competencies can be adapted to online formats, alternative assessments need further innovation to effectively replicate hands-on laboratory skills remotely, ensuring the complete attainment of course learning outcomes.

### Criteria 3: Assessments Measure the Course Outcome towards the Attainment of the Actual Programme Outcome.

Table 6 shows the evaluation details for Criteria 3 in assessing the assessments' ability to measure the course outcome towards the attainment of the actual programme outcome. The commonly conducted assessments in remote settings are laboratory reports, practical tests, and online tests. The online test is an effective tool to assess cognitive skills, the course and programme outcomes on the application of knowledge (PO1), analysis and formulation (PO2), and design solutions (PO3). Additionally, laboratory reports adequately measure students' communication skills (PO10) when they write their proposals, explain the laboratory procedures, and discuss the experimental findings in their reports. In practical tests, students are expected to develop design solutions for complex engineering problems and experiment procedures (PO5). The assessment most likely measures the student's ability to plan for the experiments and not implement the solutions, even with the home-based laboratories.

**Table 6: Evaluation Details for Criteria 3**

| Lab Course | Assessment Tool and its mapping to Programme Outcomes, Taxonomy domain and level. | Evaluation |
|---|---|---|
| CEG451 Engineering Geology | Lab Report & Observation 10% (CO3, PO10, A4) - Students proposed laboratory testing equipment and procedures to determine rock strength and resistance. Students also suggested the mitigation measures for rock slope failure and submitted a slide and video presentation.<br>Practical test 30% (CO2, PO4, P4) – No sample was observed<br>Online test 60% (CO1, PO1, C4) - Well measured | 4 (Able to measure) |
| CEG453 Geotechnical Laboratory | Technical report (CO2, PO5, P5) and Captain Diary (CO3, PO9, A4) 40% - Students were required to propose and plan laboratory tests based on the given problem statement. Students analysed the experimental data from previous experimental works.<br>Practical test 40% (CO2, PO5, P5) - No sample was observed<br>Online quiz test 20% (CO1, PO2, C4) - Well measured | 3 (Able to moderately measure) |
| CEG552 Highway & Traffic Engineering | Practical test 30% (CO2, PO5, P4)- Students were required to conduct a survey on pavement distress along a few major roads in the UiTM Penang campus, rate the pavement condition using a suitable method and suggest innovative technology for the maintenance works.<br>Laboratory report and observation 10% (CO3, PO10, A4) – Well measured<br>Online tests 60% (CO1, PO3, C4) - Well measured | 4 (Able to measure) |
| CEM472 Mechanical & Electrical Engineering | Practical test 30% (CO2, PO5, P4)- Students submitted video presentations for two home-based experiments. In the first experiment on illuminations, the students set up the experimental work to show how artificial lights (i.e. incandescent lamps, compact fluorescent lamps, etc) operate.<br>In the second experiment addressing sustainable development, students build a sustainable model with recycled materials to improve the existing infrastructure project, emphasising Mechanical & Electrical Parts. Students were required to explain the impacts of the model.<br>Lab Report 10%- (CO3, PO10, A4) For a mini project, students were required to analyse and choose a suitable approach to providing an electric power supply and distribution system for a school for the next 25 years.<br>Online test 60% (CO1, PO1, C4) - Well measured | 4 (Able to measure) |
| CEW545 Environmental Laboratory | Practical test 40% (CO1, PO5, P5) The test was performed using an online interview method. Students were asked about their experiment objective, conduct, expected results and conclusion, errors, and precautions. Students need to demonstrate how the experiment should be conducted using available resources at home.<br>Lab Report 20% (CO1, PO5, P5), (CO3, PO9, A4) The students (group work) were required to submit a video presentation and report to demonstrate the conduct of the chosen experiments using available resources at home (home-based experiment).<br>Online test 20% (CO2, PO2, C4) – Well measured | 4 (Able to measure) |

In summary, the result of the evaluation for Criteria 1 shows that the alternative assessments used in the laboratory courses are '*much relevant'* to the knowledge profiles of the courses. All lab courses except the Geotechnical Laboratory scored 4 (Much Relevant), which indicates a good agreement that the alternative assessments are able to develop the essential knowledge profiles of the courses. For Criteria 2, the findings show that all five lab courses scored 3, which indicates the alternative assessment methods are *'quite suitable'* to develop the intended course outcomes of the courses. For Criteria 3, the evaluation shows that all the lab courses except the Geotechnical Laboratory score 4 '*able to measure'* indicates that the alternative assessments for the laboratory courses are able to measure the course outcomes towards actual programme outcomes. The Geotechnical Laboratory scores lowest among all due to the nature of the course, which requires more hands-on physical experience in the learning activities. None of the lab courses were able to achieve the best performance in replacing the actual laboratory by scoring 5, which indicates the insufficiency of alternative assessment in assessing the psychomotor domain, and these have been displayed clearly in Table 7.

**Table 7: Summary of Evaluation for Each Criterion**

| Laboratory Course | Result of evaluation |
|---|---|

| | Criteria 1 | Criteria 2 | Criteria 3 |
|---|---|---|---|
| CEG451: Engineering Geology | 4 | 3 | 4 |
| CEG453: Geotechnical Laboratory | 3 | 3 | 3 |
| CEG552: Highway & Traffic Engineering | 4 | 3 | 4 |
| CEM472: Mechanical & Electrical Engineering | 4 | 3 | 4 |
| CEW545: Environmental Laboratory | 4 | 3 | 4 |

The alternative assessment in the laboratory courses during the pandemic allows the students to apply most of the relevant knowledge in the course (WK1 - natural sciences, WK2 - mathematics, WK3 - engineering fundamentals, WK4- specialist knowledge, WK5 - Engineering design, WK8 - Research literature); to design a procedure or protocol to be carried out in the laboratory experiment and conclude findings for a given laboratory data. However, there are limitations to these alternative assessments in assessing the student's knowledge in performing the laboratory work in real-time using the right equipment. The lecturers cannot observe and evaluate the student's knowledge in preparation, handling and operation of the experimental equipment's compliance to safety and health and make important decisions during the laboratory activities based on their fundamental engineering knowledge (WK4 - specialist knowledge and WK6 - engineering practice). These findings show the inadequacy of the online remote assessment in assessing the psychomotor domain.

Although home-based experiments are likely to be a good option during the pandemic, the observed substituted equipment and tests are not always relevant. They lightly relate to engineering principles and the real behaviour of the tested materials, structures or phenomena. Nonetheless, some intended course learning outcomes in cognitive, such as fundamental engineering knowledge application and verification, results in analysis and discussion, and affective domains, such as communication skills and teamwork skills, are measured directly towards true attainment. Besides, the alternative assessments show good constructive alignment and give acceptable measures of the course learning outcomes; thus, direct and true attainment of the programme outcome is evident.

## CONCLUSION AND RECOMMENDATION

This paper evaluates the implementation of alternative assessments on laboratory courses that address the psychomotor learning domain for a civil engineering degree programme offered at Universiti Teknologi MARA Pulau Pinang during ODL. This study adopts a qualitative case study approach based on document analysis. In conclusion, the alternative remote assessments can effectively assess students' knowledge profiles on engineering fundamentals (WK3) and engineering design (WK5) but hardly assess the true attainment of student engineering practices (WK6) and specialist knowledge (WK4) in laboratory conduct. In addition, learning outcomes associated with the psychomotor and affective domains are less effective in remote settings than in conventional practices. Most of the remote assessments can only develop psychomotor skills up to level P2 (i.e. awareness).

Thus, several suggestions were made for continual quality improvement of the programme: (1) the intended learning outcomes need to be revisited and improved for good constructive alignment in teaching, learning and assessment; (2) more alternative assessments such as virtual laboratory or simulation projects should be explored and implemented to develop higher psychomotor skills P3 (i.e. imitation) and P4 (i.e. operate and construct model); and (3) laboratory courses with a few must-learn experiments could be identified and chosen to be conducted physically to enhance the student knowledge on engineering practices. When there are limitations for an alternative assessment to meet the intended learning outcomes and learning domains, they shall be modified and adapted to suit the current practices that would still contribute to the true attainment of a set of programme outcomes. Utilising digital learning tools, for example, a virtual concrete laboratory simulating a concrete laboratory environment can be designed to assess the student's ability to conduct the entire concreting processes virtually: from mix design, preparation of materials, casting, fresh properties testing, compaction, operating some instrument and curing etc. Students' practical abilities can also be assessed

when they can apply appropriate engineering software to investigate the behaviours of engineering materials, structures or phenomena. When a home-based experiment is needed, the department shall provide relevant and safe tools and materials for the students to carry out the experiment. This will help the students correctly observe and verify the experiment results with fundamental engineering knowledge.

Findings from this study are able to provide the engineering lecturers with a better understanding of the currently practised remote assessments and provide continual quality improvement strategies so that the psychomotor learning domain can be accurately assessed to reflect the true programme outcome attainment and fulfil the requirements outlined by the professional bodies.

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## AUTHORS' CONTRIBUTION

Nur Asmaliza Mohd Noor, the first author, wrote the abstract, conclusion, and methodology. Oh Chai Lian, the corresponding author, conducted the fieldwork and wrote the analysis and discussion. Mohd Azuan Tukiar and Wardah Tahir contributed to the background and literature review. Che Maznah Mat Isa conducted fieldwork, provided future recommendations, and reviewed the paper's structure and continuity.

## CONFLICT OF INTEREST DECLARATION

We certify that the article is the original work of the authors and co-authors. The article has not received prior publication and is not under consideration for publication elsewhere. This research/manuscript has not been submitted for publication, nor has it been published in whole or in part elsewhere. We testify to the fact that all Authors have contributed significantly to the work, validity and legitimacy of the data and its interpretation for submission to Jurnal Intelek.

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