e-ISSN: 2600-7568

Available online at
https://journal.uitm.edu.my/ojs/index.php/

GADING Journal for the Social Sciences 29(2) 2026, 156 – 169

GADING Journal for the Social Sciences

# AP_Lab: A Digitally Enabled Practical Assessment for Laboratory-based Practical Assessment in Engineering Education

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ARTICLE INFO

*Article history:*
Received 12 November 2025
Revised 30 June 2026
Accepted 21 July 2026
Online first 15 August 2026
Published 31 October 2026

*Keywords:*
e-assessment
student assessment
remote laboratory applications in engineering
digital education
educational technology

*DOI:*
https://doi.org/10.24191/gading.v29i2.839

ABSTRACT

In laboratory courses, students' practical performance must be evaluated systematically, and records must be kept reliably, clearly, and easily accessible. This study introduces the AP_Lab system, engineered with methodologies for conducting online practical assessments and providing a storage platform to facilitate laboratory instruction and evaluation. The system combines all course requirements, including the syllabus, lab manual, assessment rubrics, Bloom's taxonomy alignment, and standard operating procedure (SOP) compliance. The AP_Lab system has several connected interfaces for entering data, recording assessments, and tracing them back. Two test-run sessions were held to evaluate the system adequacy, the usability of the user interface and the functional integrity of the navigation links. The insights gained during the test runs were considered to further improve system functionality and design. The first test run included a group of teachers who had taught in a lab to ensure that the assessment workflow was both useful and appropriate. The AP_Lab system enabled rubric-centered assessment of individual procedural performance and group teamwork behaviour, while allowing assessors to replay video evidence and store all marks, comments and evidence links in a single retrievable record. These strengthen assessment traceability and reduce reliance on fragmented paper-based marking. User evaluation indicated high acceptance among students (n = 30) and lecturers (n = 10), with excellent reliability (Cronbach's □ = 0.92 overall) and high mean satisfaction (4.21 □ 0.5). Although lecturers rated the system slightly higher than students, the difference was not statistically significant.

## 1. INTRODUCTION

Laboratory practicals remain a key part of engineering education since they link what learnt in class with real-world experience, procedural skills, teamwork, and professional judgement. These help students

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become skilled professionals and shape their future careers. Recently, remote, virtual, and hybrid laboratory models have become more popular in higher education. These models offer students more options for getting involved and are more flexible and scalable. Recent literature indicates that online and virtual laboratories are now regarded as established pedagogical environments rather than temporary alternatives, with an increasing focus on design quality, learner experience, and the incorporation of suitable assessment strategies (Kurtz et al., 2025; May et al., 2023).

Previous studies also support the educational value of online and virtual environments, which can enhance performance. Li and Liang (2024) stated that in a meta-analysis of engineering education studies, virtual laboratories can enhance student performance when effectively incorporated into the curriculum. Simultaneously, modern reviews underscore that the efficacy of online and virtual laboratories is significantly contingent upon their design, scaffolding, and assessment. Accessibility, inclusivity, collaboration, and assessment design are now perceived as important quality factors instead of just technical ones (Li & Liang, 2024).

Even with these improvements, there is still a problem: how to fairly, consistently, and effectively test laboratory competence. Laboratory learning encompasses more than cognitive attainment. It also involves psychomotor skills, emotional conduct, communication, and adherence to safe professional practices. Nikolic et al. (2023) highlighted that engineering laboratory learning objectives span the cognitive, psychomotor, and affective domains, and that assessment alignment across these domains remains inconsistent across disciplines. Recently, Nikolic et al. (2025) asserted that laboratory assessments must be organised around verifiable learning objectives to preserve validity and integrity across traditional, recorded, remote, simulated, and virtual laboratory formats (Nikolic et al., 2025). In parallel, Nandhitha and Roslin (2025) emphasised the necessity of creating OBE-aligned frameworks that clearly link laboratory tasks, rubrics, and performance indicators (Nandhitha & Roslin, 2024).

In many engineering courses, there are several challenges, including large student numbers, limited assessor time, manual scoring, fragmented evidence storage, and difficulties retrieving records for moderation, auditing, or continuous quality improvement (CQI). These limitations are particularly problematic when evaluating psychomotor and affective performance, as these outcomes are highly observation-dependent and may be assessed inconsistently if the scoring process lacks structured evaluation and proper organisation. Recent work on rubrics in engineering practical courses has demonstrated that analytic rubrics can improve transparency and better capture individual performance, particularly when conventional methods fail to assess psychomotor achievement adequately (Derahman et al., 2024).

This study introduces AP_Lab, a database-supported laboratory practical assessment platform designed to improve the consistency, flexibility, and traceability of laboratory evaluation, in contrast to traditional practical assessments that are highly dependent on in-situ observation and manual documentation. The system was built around the course syllabus (Hydraulics), laboratory manual, rubric assessment, Bloom's taxonomy, and operational laboratory rules. AP_Lab centralises assessor workflows and evidence that is used to assess on a single platform. It helps keep track of scores for both practical skill tests and laboratory activities. It also allows reviews at different times, easy record retrieval, and documentation for quality checks and audits. The practical significance of the system lies not in replacing physical assessment in laboratory teaching. Rather, it is to strengthen the assessment infrastructure and records in laboratory teaching. This is useful especially in flexible and blended delivery contexts, where recorded evidence, distributed assessors, and traceable documentation are increasingly important. Related recent work in environmental engineering and non-physical/open-ended laboratory delivery also supports the continued relevance of flexible laboratory assessment models (Bolong et al., 2025). These models can enhance engagement and learning outcomes across various educational settings, including increased student participation and improved understanding of complex concepts.

Previous studies on virtual and online laboratories largely emphasise delivery, feasibility, accessibility and cognitive learning outcomes. However, they give comparatively less attention to the practical problem of assessing laboratory competence (especially psychomotor and affective behaviours) using explicit rubrics, traceable evidence, and consistent documentation across real teaching constraints. In particular, the literature rarely reports an integrated approach that combines rubric-aligned scoring, recorded performance evidence for review, and centralised digital record management to support moderation, audit readiness and CQI in laboratory practical assessment. Accordingly, this paper aims to describe the development of AP_Lab and to report its preliminary validation through structured test runs with lecturer and student users. Specifically, the study examines the adequacy of the information fields, the usability of the interface, the correctness of interface linkages, and the suitability of the platform for supporting practical tests and laboratory activity assessments in civil engineering laboratory courses. This study, therefore, positions AP_Lab as a practical, low-cost, and institutionally adaptable approach to improving laboratory assessment quality in engineering education.

## 2. LITERATURE REVIEW

### *2.1 Laboratory Practical Assessment in Engineering Education*

Laboratory practical is one of the core learning elements in engineering education due to its ability to connect theoretical principles with hands on practices such as experimental procedures, equipment handling, data interpretation, safety practices, teamwork, and professional judgement. Unlike written examinations, laboratory assessment must capture student understanding on the theory and its application by performing experiments and technical analysis. This makes laboratory assessment inherently multidimensional. Nikolic et al. (2023) showed that engineering laboratory learning objectives commonly span the cognitive, psychomotor, and affective domains. However, the alignment across these domains remains uneven across courses and disciplines. Therefore, assessment in laboratory-based courses should not be limited to final reports or numerical answers, but it also needs to provide evidence of procedural competence, communication, collaboration, and compliance with safe laboratory practice.

A robust assessment structure is vital via the increased of the needs for remote, virtual, hybrid, and non-physical laboratory delivery. Online and virtual laboratories are now discussed as established pedagogical environments rather than temporary alternatives, particularly when they are designed with appropriate scaffolding, learner support, collaboration, and assessment strategies (May et al., 2023; Kurtz et al., 2025). Furthermore, the COVID-19 pandemic accelerated their adoption as institutions sought alternatives to conventional laboratories. Meta-analytic evidence also indicates that virtual laboratories can enhance student performance when they are meaningfully integrated into engineering curricula (Li & Liang, 2024). However, these benefits depend strongly on the quality of instructional design and assessment integration especially in engineering education. In environmental and civil engineering education, flexible laboratory approaches can support student engagement and learning when the practical task is carefully structured and aligned with the intended outcomes (Bolong et al., 2025).

### *2.2 Rubric-aligned assessment for practical competence and outcome-based education*

Rubric-aligned assessment provides a practical mechanism for improving transparency, consistency, and defensibility in laboratory practical assessment. An analytic rubric breaks down practical competence into observable criteria and performance levels, allowing assessors/ lecturers to evaluate specific aspects of student performance rather than relying on a broad and inconsistence impression of competence. In engineering practical courses, analytic rubrics have been shown to better capture individual performance and psychomotor achievement, particularly when conventional assessment methods are insufficiently specific (Derahman et al., 2024). Rubrics clarify the expected standards of performance before and during the laboratory task that should be delivered by the student. While for lecturers, rubrics provide a common and consistent assessment language that can support moderation, feedback, and comparison of achievement across cohorts. Furthermore, Nandhitha and Roslin (2024) emphasised the importance of OBE-aligned frameworks that connect laboratory tasks, rubrics, and assessment indicators in engineering programmes. This is important in laboratory courses because a single activity may involve multiple outcome domains, including conceptual understanding, procedural accuracy, safety conduct, communication, and teamwork.

Pérez-Guillén et al. (2022), for example, reported positive student perceptions and engagement when e-rubrics were used to assess manual skills. Similarly, Heil and Ifenthaler (2023) noted that online assessment is most effective when assessment criteria are explicit, feedback is meaningful, and the assessment design is aligned with the intended learning objectives. However, rubrics alone do not eliminate assessor subjectivity. Their effectiveness depends on the clarity of criteria, the quality of descriptors, assessor calibration, and the availability of evidence to support judgement. This is especially relevant in practical laboratory assessment, where procedural errors, unsafe practice, or poor communication minor may be missed if the assessment relies only on immediate observation.

### *2.3 Digital and database-supported assessment platforms for traceability and continuous improvement*

Digital assessment platforms are increasingly important in higher education because they can improve the management, accessibility, and analysis of assessment evidence. In laboratory courses, conventional paper-based marking and spreadsheet-based records may be sufficient for small-scale activities, but they become less efficient when assessment involves multiple students, assessors, rubric components, practical sessions, and evidence files. Fragmented records also make it difficult to retrieve evidence for moderation, auditing, appeal handling, and continuous quality improvement. Therefore, the importance of digital assessment is not limited to administrative convenience, but also emerging assessment tools that support feedback quality, assessment transparency, and evidence-informed decision-making rather than merely digitising existing manual processes (Sembey et al., 2024).

User acceptance is another important consideration for digital assessment platforms. A technically functional system may still fail if lecturers or students perceive it as difficult, time-consuming, or poorly aligned with teaching practice. Research on digital learning environments shows that interface coherence, navigation clarity, and efficient task flow influence user experience and system adoption (Syamala et al., 2025). In addition, lecturers' confidence, self-efficacy, and perceived usefulness affect the integration of digital technologies into higher education teaching practice (Azanza et al., 2024). Student satisfaction with online and technology-supported learning is also influenced by system quality, interaction design, and the extent to which the tool supports learning and assessment needs (Al-Khatib et al., 2024). These findings suggest that any laboratory assessment platform should be evaluated not only for technical functionality but also for usability, perceived fairness, assessment efficiency, and suitability for practical skill evaluation.

## 3. METHOD

### *3.1 AP_Lab System Design Development*

The AP_Lab system was developed using Microsoft Access as the core database and assessment interface platform. The system was designed as an assessment and storage system, where the assessor can input student information, rubric criteria, performance records, and related documents, which can be stored centrally. The system design included form interfaces, database entries, and linked navigation structures, developed based on the course syllabus, laboratory manual, rubric assessment, Bloom's taxonomy, and controlled laboratory operating requirements. Figure 1 shows the summary of the AP_Lab conceptual architecture, including the database, support tools, and assessment outputs.

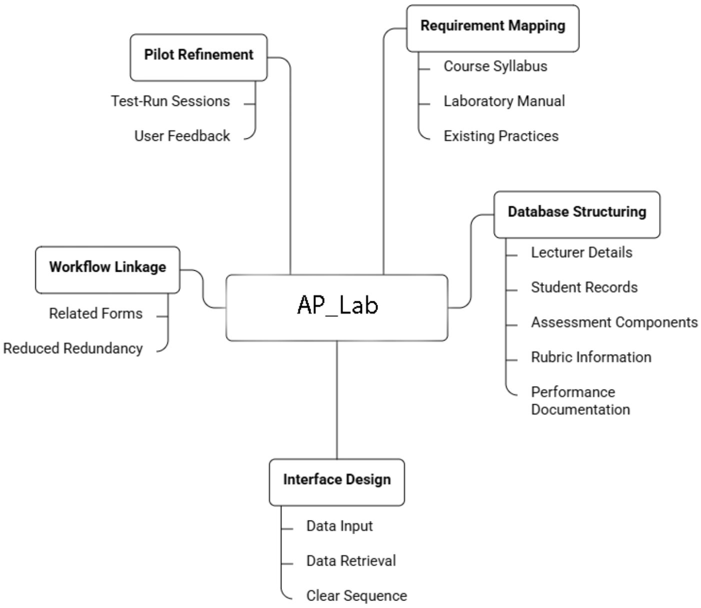


**Fig. 1.** The conceptual architecture of the AP_Lab

### *3.2 Supporting Tools and Operational Infrastructure*

The system relied on several low-cost supporting tools in addition to the database platform. These included Closed-Circuit Television (CCTV) for laboratory monitoring, a video recorder for capturing student demonstrations and a sound system for lecturers' instructions. A mobile application (e-Disguise Code Registration Apps) was also developed to support registration, motion observation, sound-level checking, and speech-to-text conversion. In practical terms, these tools supported evidence capture rather than automated grading. These allow student performance to be reviewable, archivable, and less dependent on immediate in-person observation.

### *3.3 Practical Test Assessment*

The practical test consists of two components. The first component is a demonstration component in which students set up the apparatus, prepare samples, and demonstrate the experiment according to the procedure. The second component is the questioning component, in which students respond to questions related to the objectives, concepts, and understanding of the experiment. This practical test was organised in the laboratory for the Hydraulic course, involving 30 Diploma of Civil Engineering students at Universiti Teknologi MARA. The AP_Lab is supported by video and audio recording. Prior to the test, students need to register the e-Disguise app for audio recording. The student’s procedural demonstration was recorded on video, while responses to the lecturer's questions were recorded as audio. These recordings were then uploaded through the broader system workflow and reviewed by the lecturer during the assessment process.

### *3.4 Assessment Functions Supported by AP_Lab*

AP_Lab supports two main forms of laboratory assessment:

a. Practical Skill Test

The practical skill test evaluates students’ ability to demonstrate the experiment correctly and explain the underlying concepts. High performance in this mode is associated with correct apparatus handling, proper procedural sequence, clear and orderly explanation, accurate response to questions, and confident and safe execution of the practical task. This mode primarily addresses psychomotor performance while also capturing aspects of cognitive understanding and professional communication, such as the ability to articulate procedures clearly and respond effectively to enquiries during practical tasks.

b. Laboratory Activity Assessment

In addition to formal practical laboratory sessions, the system also supports the assessment by the lecturer of students' performance during regular laboratory activities. This assessment focuses on participation and task engagement, teamwork and cooperation, personal safety practices, compliance with laboratory rules, and maintaining laboratory cleanliness and order. This mode is meant to capture key affective and behavioural aspects of the student's laboratory skills and competence that are often missed when the assessment focuses only on the final practical skill test at the end of the semester. These are summarised in Figure. 2.

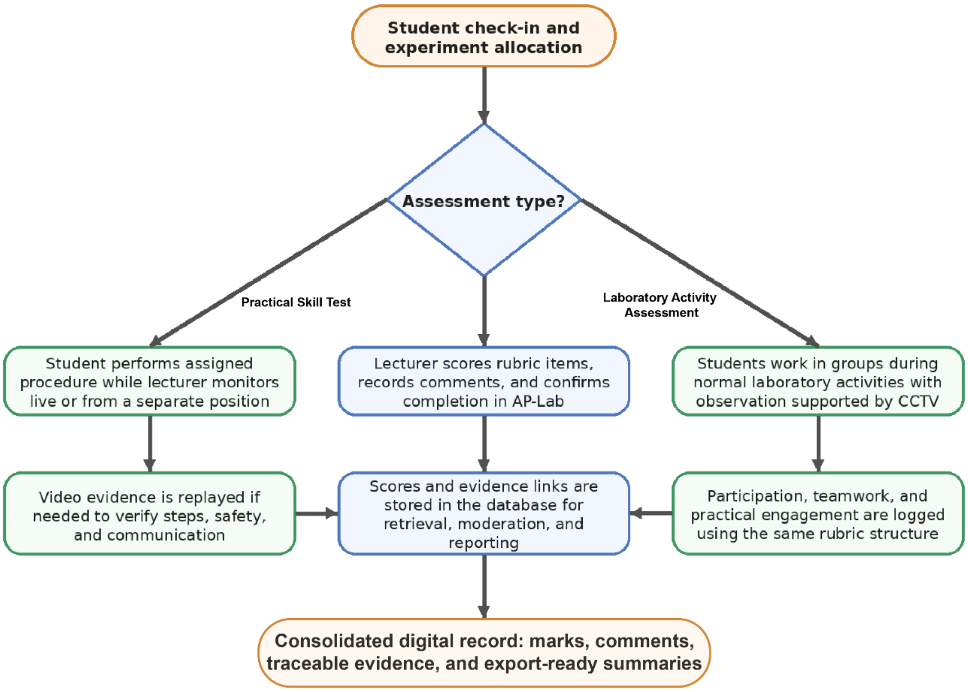


**Fig. 2.** AP_Lab workflow for practical skill test and laboratory activities assessment

### *3.5 AP_Lab Satisfaction Survey and Statistical Analysis*

A cross-sectional satisfaction survey was carried out to evaluate user acceptance of AP_Lab among 30 students and 10 lecturers who utilised the platform during the practical skill laboratory assessment. Satisfaction was measured using an eight-item questionnaire that included ease of use, rubric clarity, fairness, efficiency, confidence in video/CCTV evidence, feedback quality, suitability for practical skill assessment, and intention to continue using the system. A five-point Likert scale (1 = strongly disagree to 5 = strongly agree) was used to rate all the items. Completed responses were then analysed for internal consistency using Cronbach's alpha. The mean, standard deviation, median, frequency, percentage, and 95% confidence interval were calculated for every individual item and for the composite satisfaction score, which was computed as the average of the eight item scores. Given the unequal group sizes and the relatively small lecturer sample, the Mann-Whitney U test was used as the primary inferential test to compare satisfaction between students and lecturers. Welch's independent-samples t-test was conducted as a supplementary mean-based comparison because it is more robust than Student's t-test under heteroscedasticity and unequal sample sizes (student $n = 30$; lecturers $n = 10$). Since the lecturer sample was relatively small and the outcome was derived from Likert-scale items, the Welch test was used as a supplementary test and interpreted by applying the Mann-Whitney U test as a distribution-free sensitivity check ($p < 0.05$). Cohen's d was used to estimate effect size.The magnitude of the group difference was interpreted using conventional benchmarks for Cohen's d (≈0.2 small, 0.5 medium, 0.8 large). Based on the observed means and standard deviations, the effect size corresponds to a moderate difference in satisfaction in favour of lecturers. A significance level of $p < 0.05$ was adopted for all inferential analyses.

## 4. FINDING & DISCUSSION

### *4.1 AP_Lab Development*

Figures 3 and 4 show the interface of AP_Lab for practical skill tests and laboratory activities assessments, respectively. These interfaces display the student's details, along with the essential elements and criteria for assessment. The interface analysis shows that AP_Lab successfully turned practical assessments into an integrated digital workflow that begins with identifying students and assigning experiments and ends with a consolidated assessment record. The system has three core functions: (i) student verification and traceability through student background data, matric/QR code information linked to assessment records; (ii) evidence-based observation through live or replayable video/CCTV footage; and (iii) structured scoring through rubric-driven marking forms for both individual practical skill tests and group laboratory activities.

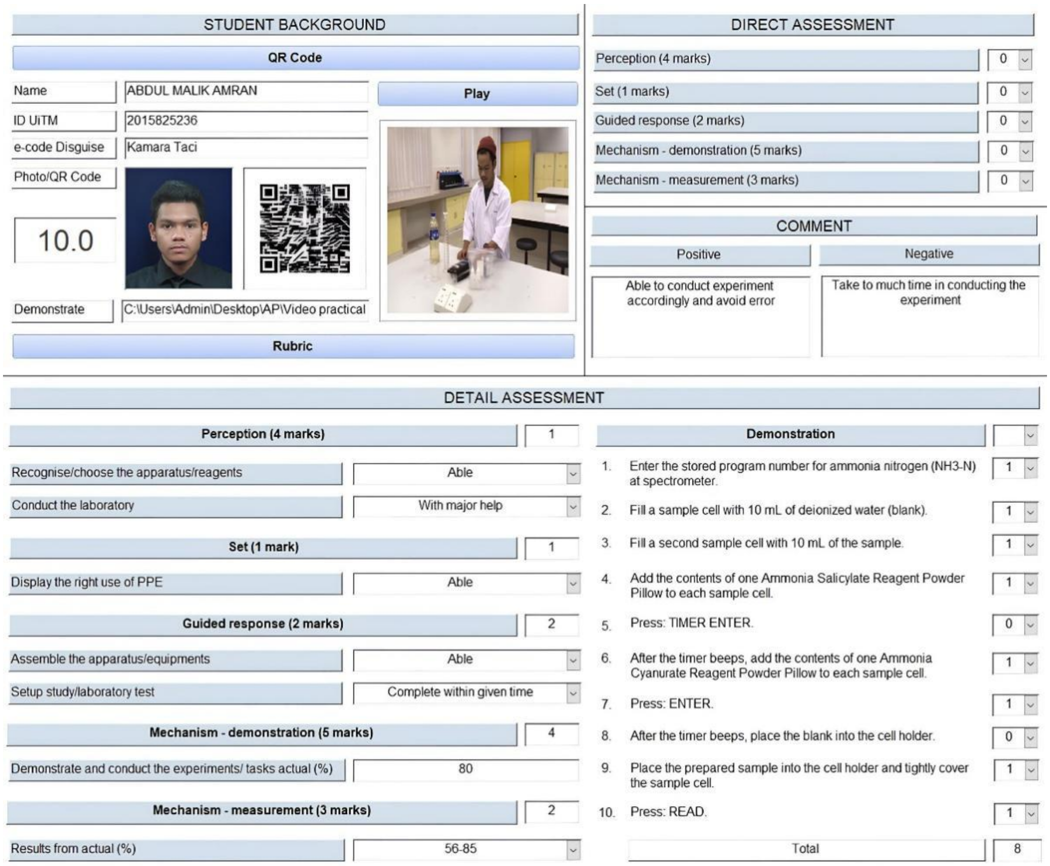


**Fig. 3**. The AP_Lab interface for laboratory skill test assessment

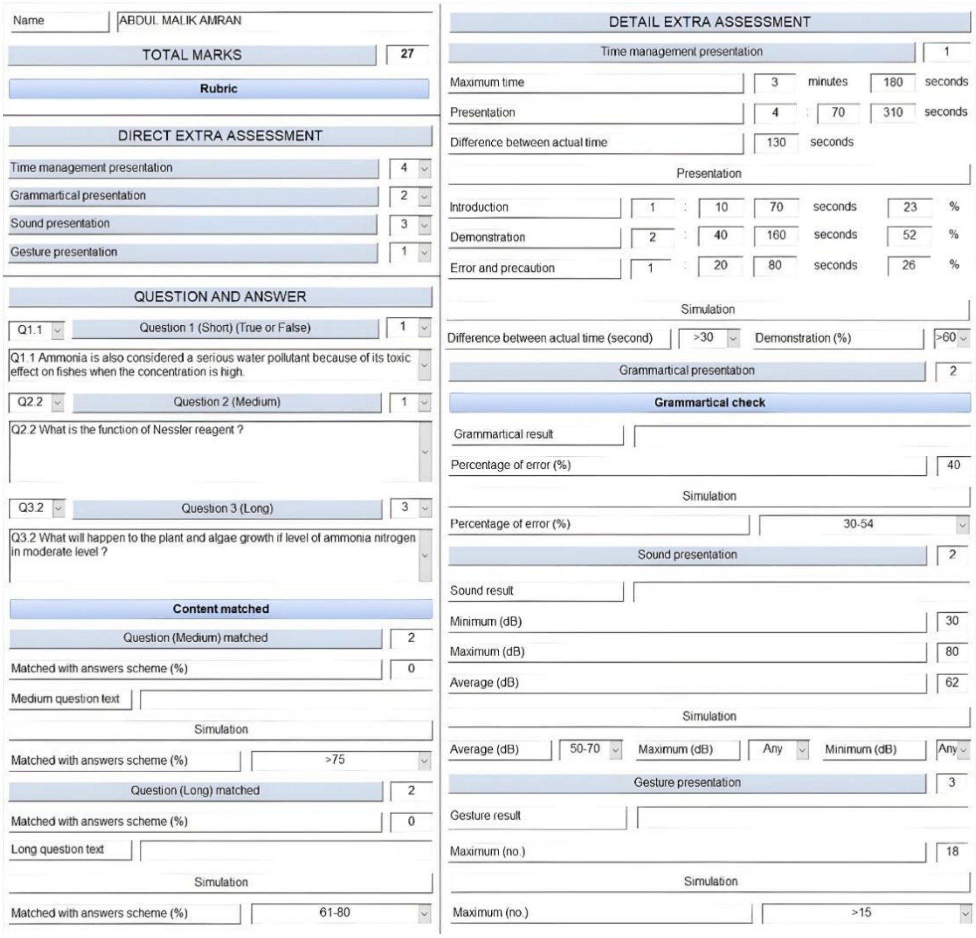


**Fig. 4.** AP_Lab Interface for laboratory activities assessment

The individual assessment interface (Figure 3) illustrates that lecturers can evaluate procedural performance using direct criteria, including perception, guided response, mechanism demonstration, and mechanism measurement, while simultaneously documenting feedback, recording comments, and the measured experimental result. In particular, the group assessment interface (Figure 4) showed that AP_Lab could measure teamwork-related criteria and behaviours such as discipline, cooperation, idea generation, and organisation, while simultaneously allowing lecturers to watch recorded video playback. The same platform supports both practical skill tests and routine assessments for student laboratory activities. All marks, comments, and evidence links are stored in a retrievable digital record on the same platform. All of these features suggest that AP_Lab strengthens assessment traceability, reduces dependence on fragmented paper-based markings, and enables lecturers to revisit performance evidence before confirming final marks. This is particularly useful for procedural tasks that could be overlooked, such as minor errors, safety compliance, or communication behaviour.

From a pedagogical point of view, AP_Lab reflects the principles of authentic and technology-supported assessment because it captures students' performance during real laboratory tasks instead of relying on written reports at the end. This is significant because recent research shows that online tests are most effective when the criteria are explicit, align with learning objectives, and provide prompt feedback and structured reporting (Heil & Ifenthaler, 2023). Therefore, the rubric-centred design of AP_Lab is a strength, as recent research on e-rubrics shows that digital rubric systems can provide clearer criteria for teaching and learning and strengthen assessment and feedback processes when implemented correctly (Heil & Ifenthaler, 2023). The system's use of video evidence is also in line with new research that shows video-based assessment can produce valid judgements of collaborative or performance-based work. However, there is still some subjectivity on the part of the assessor, which can be lessened by rubric refinement and assessor training. In a comprehensive study, video-based peer assessment of teamwork was found to be reliable and appropriate for decision-making, but further refinement of the marking rubric and assessor preparation is needed (Roberts et al., 2024). This is relevant for AP_Lab, as the platform clearly improves assessment management, but stronger claims about fairness, consistency, or learning gains should be made only after reporting data on inter-rater reliability, usability, and user perceptions. In addition, research in engineering education shows that digital and virtual laboratory approaches improve flexibility, accessibility, and performance support. However, they are usually best used as a supplement to hands-on lab work rather than a full replacement (Li & Liang, 2024; Wahyudi et al., 2024). Therefore, AP_Lab is best suited as a blended assessment tool because it keeps live practical work while digitising scoring, observation, and evidence capture. This is also timely because recent work on laboratory assessment integrity argues that relying heavily on unsupervised laboratory reports creates validity and cheating risks, whereas more diverse, observable assessment approaches better verify cognitive, psychomotor, and affective learning outcomes (Nikolic et al., 2025).

### *4.2 AP_Lab User Satisfaction and Preliminary Statistical Evaluation*

A simple satisfaction analysis was performed to evaluate the acceptance of AP_Lab for practical skill laboratory assessment among students ($n = 30$) and lecturers ($n = 10$) using an eight-item, five-point Likert questionnaire. The instrument exhibited exceptional internal consistency, as evidenced by Cronbach's alpha values of 0.92 for students, 0.90 for lecturers, and 0.92 overall, indicating strong reliability (Table 1). The mean composite satisfaction score for students was $4.14 \pm 0.51$, while the lecturers recorded a higher mean score of $4.41 \pm 0.43$. The overall mean score across all respondents was $4.21 \pm 0.50$, indicating high satisfaction with the AP_Lab system. In terms of response tendencies, 85.4% and 97.5% of student and lecturer responses, respectively, fell within the 'agree' or 'strongly agree' categories. Moreover, the most highly rated parts of the system were assessment efficiency (mean = 4.35), support for practical skill assessment (mean = 4.30), and clarity of the rubric structure (mean = 4.28). Lecturers showed a higher "Agree/Strongly agree" response tendency (97.5%) than students (85.4%), which may be due to the role-based perceived usefulness as assessors. The lecturers directly experienced the system as part of the assessment process and may have been more sensitive to the learning curve and procedural and recording logistics. Furthermore, the percentage may be more sensitive due to smaller lecturer group sizes, and it should be interpreted cautiously. Although lecturers reported slightly higher satisfaction than students, the difference was not statistically significant (Mann-Whitney $U = 111.5$, $p = 0.233$; Welch's $t\,(18.37) = 1.67$, $p = 0.113$), suggesting that both respondent groups viewed the system positively and comparably.

**Table 1.** Satisfaction Analysis of the AP_Lab System

| **Metric** | **Students (n = 30)** | **Lecturers (n = 10)** | **Overall (n = 40)** |
|---|---|---|---|
| Reliability (Cronbach's alpha) | 0.92 | 0.90 | 0.92 |
| Mean Satisfaction Score (± SD) | 4.14 ± 0.51 | 4.41 ± 0.43 | 4.21 ± 0.50 |
| Response Tendency (Agree / Strongly Agree) | 85.4% | 97.5% | — |

The satisfaction results reveal that both students and lecturers agreed that AP_Lab is a good digital platform for practical skill laboratory assessment. The high overall mean scores indicate that users perceived the system to be useful, structured, and appropriate for evaluating students' hands-on laboratory performance. In particular, the high ratings for rubric clarity and assessment efficiency are in line with prior research indicating that the quality of assessment tools, interaction design, and technology reliability influence user satisfaction in engineering-related settings (Al-Khatib et al., 2024; Heil & Ifenthaler, 2023). The high rating for AP_Lab's suitability for practical skill assessment aligns with research on e-rubrics for manual skills assessment, where students reported positive perceptions and satisfaction when clear digital criteria were used to support performance evaluation (Pérez-Guillén et al., 2022).

Although lecturers rated AP_Lab slightly more positively than students, the non-significant difference indicates that the system was broadly acceptable across user groups rather than being beneficial to only one stakeholder category. This is important because successful adoption of digital assessment systems depends not only on student usability but also on lecturer confidence, perceived usefulness, and willingness to integrate the tool into teaching practice. Recent evidence shows that positive attitudes and adequate training improve lecturers' self-efficacy and increase their interest in using digital technologies in higher education (Azanza et al., 2024). From a wider engineering-education perspective, the present pattern is also consistent with recent meta-analytic evidence that digitally enabled laboratory approaches can improve educational effectiveness when they are well integrated with course objectives, accessible to users, and used to support rather than replace authentic practical tasks. Therefore, the satisfaction results support the argument that AP_Lab is a feasible and acceptable blended assessment innovation for laboratory-based courses. However, future studies should extend beyond satisfaction by examining usability, inter-rater reliability, marking time reduction, and links between AP_Lab use and student performance outcomes (Li & Liang, 2024).

### *4.3 Advantages and Limitations of AP_Lab*

AP_Lab offers several clear benefits as a digital platform for laboratory-based practical skill assessment. Its main strength lies in integrating student identification, rubric-based scoring, assessor comments, and visual evidence into a single system. This improves documentation consistency and strengthens the traceability of assessment decisions. Thus, it is useful for laboratory settings, where performance is often observed in short stages, and it can be challenging to reliably track documents using conventional paper-based methods. In addition, the rubric-driven structure of AP_Lab supports more explicit marking criteria and a standardised assessment workflow. These can assist both assessors and students in understanding what is expected during the practical test. Previous research on online and technology-enhanced assessment indicates that structured digital assessment systems are most effective when they clarify expectations, facilitate feedback, and closely align with intended learning outcomes (Heil & Ifenthaler, 2023; Sembey et al., 2024). From this perspective, AP_Lab is well-positioned as a blended assessment tool that supports authentic evaluation of laboratory performance while preserving a retrievable digital record.

Another important advantage of AP_Lab is its usability potential for assessment management. The system could keep mark records and related assessment evidence in a single platform. Thus, it can avoid duplicates, keep records organised, and support reviews or adjustments after assessments. This is relevant for practical skills assessments, where lecturers may need to revisit procedural steps, safety-related behaviours, or communication performance before confirming students' final marks. Educational technology research consistently demonstrates that systems with stronger interface coherence, clearer navigation, and efficient task flow are more likely to be accepted and used effectively in practice (S et al., 2025). In this way, AP_Lab's integrated workflow supports not only scoring efficiency but also better administrative control over practical assessment documentation. This can lead to improved outcomes in educational settings by ensuring assessments are better organised and more accessible for both educators and students.

Despite these strengths, AP_Lab also has some limitations. At this stage, the platform can be described as a functionally promising and practically useful assessment innovation, but not yet as a fully validated assessment system. The existing evidence predominantly supports feasibility, usability, and operational coherence rather than long-term educational efficacy. As highlighted in feasibility and pilot-study literature, preliminary system testing is beneficial for assessing a tool's intended functionality. However, it should not be regarded as definitive evidence of its impact on learning outcomes (Eldridge et al., 2016). Similarly, broader reviews of emerging technologies in higher education assessment caution that digital tools often advance more rapidly than the evaluation frameworks used for validation, making it difficult to distinguish between proof of concept and robust empirical validation (Sembey et al., 2024). This means AP_Lab still needs stronger evidence in areas such as inter-rater reliability, task completion efficiency, repeated-use usability, and user satisfaction across larger student cohorts.

Another limitation is that the effectiveness of AP_Lab still depends on the interface quality, assessor familiarity, and technical reliability. A comprehensive system can also become visually dense or operationally demanding if navigation is not sufficiently streamlined. This can lead to user frustration and hinder effective learning outcomes. In practice, even well-designed educational tools may not be adopted if users find them cognitively demanding, difficult to learn, or inconvenient in real-time teaching contexts (S et al., 2025). In addition, while rubric-based assessment improves structure and transparency, rubrics do not remove assessor subjectivity. The quality of judgement is still based on the clarity of the criteria, the consistency of interpretation, and the extent of assessor calibration. Therefore, AP_Lab should not be positioned as a tool that eliminates judgement, but as a system that supports more organised, clearer, and easier-to-review work. Overall, the AP_Lab's contribution lies in improving the coherence, traceability, and practical management of laboratory assessment. Its long-term value will depend on continued improvement and stronger empirical validation.

## 5. CONCLUSION

AP_Lab offers a practical digital assessment workflow for laboratory-based civil engineering courses that combines structured digital marking with video, audio, and CCTV-supported evidence capture. It also helps preserve observation of hands-on performance while improving record consolidation and assessor flexibility. The primary contribution is enabling a more manageable, documented assessment process for psychomotor and affective learning outcomes in authentic laboratory contexts. Overall, the findings show that Ap_Lab achieved high satisfaction and strong acceptance among users (students and lecturers), as supported by the scale's reliability. Satisfaction levels were similarly high in both groups, with no statistically significant difference. Therefore, these results support the feasibility of AP_Lab as an acceptable platform for practical laboratory assessment and justify broader pilot implementation.

## 6. ACKNOWLEDGEMENTS/ FUNDING

The authors would like to acknowledge the support of the Faculty of Civil Engineering, Universiti Teknologi MARA (UiTM), for providing the facilities in this research.

## 7. CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefit, commercial, or financial conflicts and declare the absence of conflicting interests with the funders.

## 8. AUTHORS' CONTRIBUTIONS

**Zadariana Jamil:** carried out the study, did the data analysis, wrote, and revised the article. **Mohd Fairuz Bachok:** conceptualised the research idea and framework and developed the system. **Noraida Mohd Saim, Zulhafizal Othman, and Farah Wahida Mohd Latib:** assisted with the design of the system content and carried out the study.

## 9. DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES

This manuscript was developed with the assistance of ChatGPT and Quillbot for the purpose of improving academic writing and proofread grammar and style. The tool/service supported the author(s) in reviewing and refining the content, and the authors assume full responsibility for the final version submitted for publication.

## 11. DATA AVAILABILITY/SUPPLEMENTARY MATERIALS

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

## 12. ETHICS STATEMENT

Not applicable

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