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AI Usage Patterns and Effects on English Language Comprehension Among Students at Politeknik Kota Bharu

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Abstract: *This study examines the usage patterns of Artificial Intelligence (AI) technology and their effects on English language comprehension among students at Politeknik Kota Bharu. A cross-sectional quantitative survey design was employed, involving 344 students from four academic departments. Data were collected using a structured questionnaire and analysed using descriptive statistics via SPSS version 26. The findings indicate that students actively utilise AI tools for learning purposes, with ChatGPT, Google Translate, and Grammarly being the most frequently used applications. Overall, AI usage demonstrated a positive impact on English language comprehension across four key domains: writing, reading, speaking, and listening. Writing skills recorded the highest level of improvement (mean = 4.07), followed by reading comprehension (mean = 4.00). Speaking (mean = 3.89) and listening skills (mean = 3.88), meanwhile, showed comparatively moderate gains. The stronger improvement in text-based skills reflects the predominance of AI tools that provide immediate feedback, language correction, and content clarification. Despite these positive outcomes, the study also identifies challenges such as limited exposure to AI-focused instruction, variations in access to technology, and the need for greater lecturer readiness in integrating AI into teaching practices. Ethical considerations, including data privacy and responsible AI use, are also highlighted. The findings underscore the potential of AI technology to enhance English language learning in the TVET context and* *suggest that strategic integration of AI training within the curriculum could improve learning outcomes. From a broader perspective, this study provides empirical evidence to inform educational policy and institutional planning aimed at promoting effective, ethical, and inclusive AI adoption in technical and vocational education.*

Keywords: *artificial intelligence, English language learning, TVET education, language comprehension, student engagement*

1. INTRODUCTION

In the era of globalization and rapid technological advancement, the integration of technology in education has become an urgent necessity. One of the emerging technologies that has gained significant attention is Artificial Intelligence (AI). AI technology is increasingly recognized for its potential to transform educational practices, particularly within Technical and Vocational Education and Training (TVET). While TVET primarily focuses on equipping students with industry-relevant technical skills, language proficiency—especially in English—remains a crucial complementary skill for graduates entering a globalized workforce. Mastery of English facilitates international communication, enhances employability, and enables access to technical documentation and global knowledge resources. In this regard, AI has been identified as a promising tool to support English language learning through interactive, adaptive, and personalized approaches. A study conducted by Zawacki-Richter et al. (2019) highlighted that AI applications in language education can provide additional instructional support through more customized and learner-centred experiences.

Technologies such as AI-based language learning applications allow TVET students, who often face constraints related to time, learning pace, and academic preparedness, to engage in self-directed English learning at their own convenience (Viberg & Grönlund, 2020). This is particularly relevant in the context of the students studying in Politeknik Kota Bharu, a Malaysian TVET institution, who come from diverse academic backgrounds and may have limited exposure to English outside the classroom. Many students rely heavily on lecturer-led instruction, and opportunities for extended English practice are often constrained by packed technical curricula. Within this local context, AI tools such as ChatGPT, Google Translate, and Grammarly present an opportunity to bridge language gaps by providing immediate feedback, explanations, and language support beyond formal class hours. Recent studies have also indicated that AI-supported language learning can enhance students' motivation and confidence in using English, which is especially valuable in TVET settings where communication skills are considered an added professional advantage (Chen et al., 2020).

Furthermore, AI technology supports adaptive learning by adjusting content difficulty based on learners' proficiency levels, allowing students to progress at their own pace (Xie et al., 2021). This feature is particularly beneficial for students at Politeknik Kota Bharu, where variations in English proficiency levels pose challenges for uniform instruction. AI-driven learning tools offer flexible support that complements conventional teaching methods and aligns with TVET's objective of producing competent, industry-ready graduates. With the continuous advancement of AI, TVET education is now positioned at the intersection of technology and language learning, with AI potentially strengthening English comprehension and better preparing students to compete in an increasingly global and technologically driven job market (Hwang et al., 2022).

Despite the growing body of international research on AI in education, empirical studies examining AI usage patterns and their direct effects on English language comprehension within Malaysian TVET institutions remain limited, particularly at polytechnic level. Therefore, this study addresses this gap by focusing specifically on students at Politeknik Kota Bharu, providing localized empirical evidence on how AI technologies are utilized and how they influence English language comprehension. The novelty of this study lies in its context-specific examination of AI usage patterns and their impact on multiple dimensions of English comprehension within a Malaysian TVET setting, offering practical insights for curriculum enhancement and AI integration in polytechnic education.

2. PROBLEM STATEMENT

Although polytechnics and TVET institutions in Malaysia prioritize the development of technical skills, English language proficiency among TVET students remains a significant challenge. Limited English language comprehension restricts students' ability to compete in the global job market, particularly in industries that require cross-cultural communication and engagement with technical documentation that is predominantly written in English. At Politeknik Kota Bharu, this issue is influenced by students' diverse educational backgrounds and varying levels of prior exposure to the English language.

In addition, English language instruction within the polytechnic curriculum is often constrained by limited instructional time and stronger emphasis on technical subjects. As a result, students have fewer opportunities for structured and continuous language practice, leading to persistent weaknesses in grammar, pronunciation, and text comprehension. While digital learning tools are increasingly available, challenges related to access to appropriate technology, internet connectivity, and students' familiarity with advanced learning platforms further limit the effectiveness of language learning support outside the classroom.

Artificial Intelligence (AI) technology has the potential to address these limitations by offering personalized, interactive, and flexible approaches to English language learning. However, research examining how AI influences English language comprehension within Malaysian TVET institutions, particularly at Politeknik Kota Bharu, remains limited. This is consistent with the findings of Yao et al. (2020), who noted that although AI has demonstrated positive effects in language learning contexts, its application within technical and vocational education settings is still underexplored.

Previous studies have shown that AI can enhance language learning through personalized approaches tailored to learners' levels of understanding (Dong et al., 2020). Similarly, Pham et al. (2021) found that improvements in English comprehension through AI can increase students' confidence in engaging with the global workforce. Therefore, this study seeks to examine how AI technology is utilized among students at Politeknik Kota Bharu and how it affects their level of English language comprehension within the existing TVET learning environment.

3. RESEARCH QUESTIONS

1. What is the extent of Artificial Intelligence (AI) technology usage in learning among students at Politeknik Kota Bharu?

2. What is the impact of Artificial Intelligence (AI) technology on students' English language comprehension at Politeknik Kota Bharu?

4. RESEARCH OBJECTIVES

1. Determine the usage level of Artificial Intelligence (AI) technology in learning at Politeknik Kota Bharu.

2. Analyze how the use of Artificial Intelligence (AI) technology affects the level of understanding of English among Politeknik Kota Bharu students.

5. LITERATURE REVIEW

This literature review examines recent studies and theoretical perspectives on the application of Artificial Intelligence (AI) in education, with particular emphasis on its role in English language learning. Within the context of Technical and Vocational Education and Training (TVET), the review highlights how AI technologies support language development while addressing learners' diverse needs. The section is organized into two main areas: the level of AI usage in teaching and learning, and the impact of AI technology on students' English language comprehension.

5.1 THE USAGE LEVEL OF ARTIFICIAL INTELLIGENCE TECHNOLOGY IN TEACHING & LEARNING

The use of AI technology in teaching and learning has increased significantly due to its capacity to personalize learning experiences and improve educational outcomes. Early applications of AI in education focused primarily on administrative support and basic instructional software. Over time, AI integration has expanded to include web-based intelligent systems, adaptive learning platforms, and conversational agents such as chatbots, which can function independently or in collaboration with instructors (Chen et al., 2020). While these developments demonstrate the rapid evolution of AI in education, recent literature emphasizes functionality and pedagogical value rather than technological novelty.

Several studies highlight that AI-powered systems enhance instructional efficiency by automating routine tasks such as grading and feedback, allowing educators to focus more on instructional quality (Mello et al., 2023). At the same time, AI's adaptive capabilities enable the customization of learning materials based on individual learners' progress and preferences, contributing to improved engagement and knowledge retention (Chen et al., 2020; Mello et al., 2023). However, Viberg and Grönlund (2020) caution that effective AI adoption depends not only on availability but also on students' digital literacy and institutional readiness.

From a TVET perspective, the utilization of AI is particularly relevant, as students often balance intensive technical coursework with limited time for language development. Studies conducted in vocational and higher education contexts suggest that AI-supported learning environments can compensate for restricted instructional time by offering flexible, self-paced learning opportunities (Hou, 2021). Despite these benefits, Ojha et al. (2023) and Chen et al. (2020) note that AI usage levels vary widely across institutions, often influenced by access to technology, institutional support, and educators' familiarity with AI tools. These findings indicate a gap between AI's potential and its actual implementation, especially in applied education settings such as TVET.

5.2 THE IMPACT OF ARTIFICIAL INTELLIGENCE TECHNOLOGY ON STUDENTS' ENGLISH COMPREHENSION

Existing literature consistently reports positive effects of AI technology on students' English language comprehension, particularly through personalized feedback and adaptive learning mechanisms. AI-powered tools analyze learners' performance to provide targeted feedback, enabling students to identify weaknesses and adjust their learning strategies accordingly (Mukhallafi, 2020; Hou, 2021; Zhang, 2021). Compared to traditional instruction, these tools promote learner autonomy and continuous engagement with the language.

Studies also highlight the role of AI-based conversational agents in enhancing language practice. Tools such as chatbots and virtual assistants create interactive environments where learners can practice reading, writing, speaking, and listening with immediate feedback (Mello et al., 2023; Zastudil et al., 2023). While Nazari et al. (2021) demonstrated that AI-powered writing assistants significantly improve writing accuracy and organization, other studies emphasize vocabulary development and comprehension as key benefits of AI-supported reading activities (Song & Song, 2023).

Comparatively, vocational-focused studies suggest that AI has a particularly strong impact on learners who require practical and contextualized language support. Hou (2021) found that AI-enhanced English learning in vocational colleges improved comprehension by aligning content with students' academic and professional needs. Similarly, Pham et al. (2021) reported that AI-based language learning increased students' confidence in preparing for workforce communication, an outcome highly relevant to TVET students. However, Yao et al. (2020) argue that despite these promising findings, AI research in vocational and technical education remains limited in scope and context-specific evidence is still insufficient.

More recent research on generative AI tools, such as ChatGPT, indicates their potential to accelerate learning through instant explanations, examples, and interactive feedback (Mello et al., 2023; Waseem et al., 2024). While these studies demonstrate positive outcomes in higher education and technical disciplines, most focus on general or international contexts rather than localized TVET institutions. As noted by Song and Song (2023), further empirical research is required to examine how AI tools influence multiple dimensions of English comprehension within specific educational settings.

Overall, the reviewed studies suggest that AI technology positively influences English language comprehension by supporting personalized learning, increasing motivation, and fostering learner autonomy. Nevertheless, gaps remain in understanding how AI is used in Malaysian TVET institutions and how usage patterns relate to actual language comprehension outcomes. This study addresses these gaps by examining AI usage patterns and their effects on English language comprehension among students at Politeknik Kota Bharu, thereby contributing localized empirical evidence to the existing body of literature.

6. RESEARCH METHODOLOGY

This study employed a descriptive survey design using a quantitative research methodology. A quantitative approach was selected as it allows for the efficient collection of data from a large number of respondents and facilitates statistical analysis of patterns and relationships. The survey method was considered appropriate for examining students' usage of Artificial Intelligence (AI) technology and its effects on English language comprehension. The data collected were analysed using the Statistical Package for Social Science (SPSS) version 26.

The primary research instrument was a structured questionnaire developed to align with the research objectives and research questions of the study. The questionnaire items were generated based on a review of relevant literature on AI usage in education and English language learning, ensuring content relevance and conceptual alignment. The items focused on students' frequency of AI usage in learning activities and their perceived effects on different aspects of English language comprehension, including writing, reading, speaking, and listening. Prior to full distribution, the questionnaire items were reviewed for clarity, language suitability, and relevance to the TVET context to ensure that they were easily understood by polytechnic students.

The questionnaire employed a five-point Likert scale ranging from Strongly Disagree to Strongly Agree. The Likert scale was chosen as it is widely used in educational research to measure attitudes, perceptions, and self-reported behaviours, allowing respondents to express varying degrees of agreement in a structured and quantifiable manner. This scale also enabled the calculation of mean scores and standard deviations, which were essential for addressing the research questions.

The survey questionnaire was distributed online using Google Forms. This platform was selected due to its accessibility, ease of use, and suitability for reaching a large student population efficiently. Google Forms also allowed respondents to complete the questionnaire at their convenience, which was particularly appropriate for polytechnic students who may have varying schedules due to academic and practical training commitments. Additionally, the use of an online platform facilitated accurate data collection and reduced manual data entry errors.

The questionnaire consisted of three parts. Part A collected respondents' demographic information. Part B examined students' usage of AI technology in learning, while Part C comprised 21 items measuring the influence of AI technology on English language comprehension. Descriptive analysis was conducted for Part A, while Parts B and C were analysed using mean scores and standard deviations to determine usage levels and perceived effects.

Reliability analysis was conducted using the "Reliability Analysis – Scale Alpha" function in SPSS version 26. The results indicated a Cronbach's Alpha value of 0.983 for the questionnaire, demonstrating a high level of internal consistency and confirming that the instrument was reliable for measuring the intended constructs.

Cronbach's Alpha	N of Items
.983	13

Table 1. Questionnaire reliability index

6.1 RESEARCH SAMPLE

The study sample was selected using purposive sampling, focusing specifically on students from Politeknik Kota Bharu, as the institution represents a typical Malaysian TVET context. Students from four major departments were included to ensure a diverse academic representation. A simple random sampling method was subsequently applied to select participants from each department. A total of 344 students participated in the study, comprising 151 students (43.9%) from the Department of Commerce, 123 students (35.7%) from the Department of Civil Engineering, 27 students (7.8%) from the Department of Electrical Engineering, and 43 students (12.5%) from the Department of Mechanical Engineering.

In terms of gender, 171 respondents (49.7%) were female and 173 respondents (50.3%) were male. With regard to academic level, 202 students (58.7%) were from Semester 1, 55 students (16%) from Semester 3, and 86 students (25%) from Semester 5.

While the sample size was adequate for quantitative analysis, potential limitations should be acknowledged. As participation was voluntary, self-selection bias may have occurred, with students who were more familiar or comfortable with AI tools having been more inclined to respond. In addition, variations in departmental representation may have also influenced the generalisability of the findings, as students from different academic disciplines may experience different levels of exposure to English and AI technology. These factors were considered when interpreting the results of the study.

7. RESEARCH FINDINGS

7.1 THE UTILIZATION LEVEL OF ARTIFICIAL INTELLIGENCE TECHNOLOGY IN LEARNING

The findings reveal that the top three Artificial Intelligence (AI) tools utilized by students at Politeknik Kota Bharu for learning purposes are ChatGPT (34.35%), Google Translate (31.85%), and Grammarly (13.57%). These tools play a crucial role in supporting English language comprehension, particularly in text-based learning activities. ChatGPT is frequently used for generating explanations and examples, Google Translate assists in understanding unfamiliar vocabulary and sentence structures, and Grammarly supports accuracy and clarity in writing. This pattern reflects students' preference for AI tools that provide immediate and direct assistance in completing academic tasks.

To gain insight into student experiences and perceived learning outcomes, a structured questionnaire was administered after the completion of peer-teaching sessions. The survey was distributed to all 125 participating students across the four classes. It was designed to capture both quantitative and qualitative data. The quantitative portion consisted of 10 closed-ended items rated on a 4-point Likert scale (1 = Strongly Disagree to 4 = Strongly Agree). These items evaluated various aspects of Canva usage, including perceived engagement, content comprehension, note-sharing efficiency, and overall satisfaction with Canva as a digital learning tool. Some sample survey statements included the following:

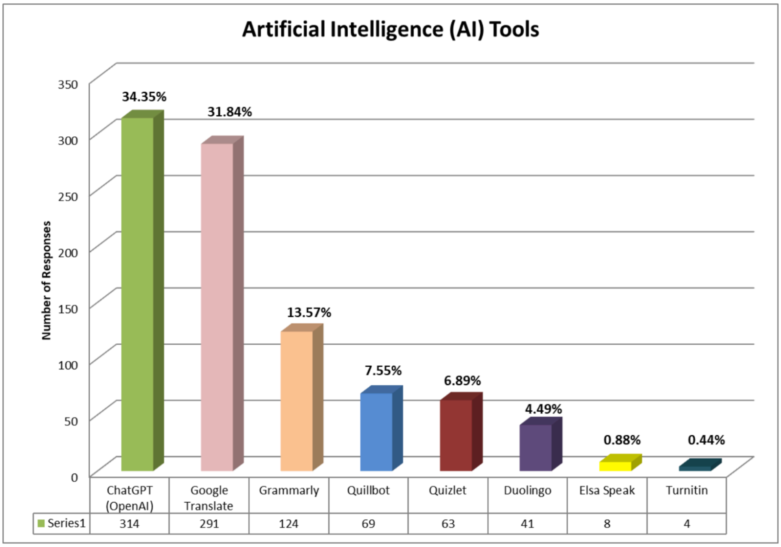

Figure 1. Artificial Intelligence (AI) tools utilized by students

The overall mean score for AI technology usage among students is 3.8038, indicating an active level of engagement with AI tools. Students reported frequent use of AI for learning activities (mean = 4.08), completing tasks (mean = 3.81), doing exercises (mean = 3.72), and completing assigned homework (mean = 3.60). These findings suggest that AI technology is primarily integrated into students' daily academic routines, particularly for individual and task-oriented learning activities.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
S1 Use AI in learning	344	1	5	4.08	.828
S2 Use AI in completing tasks	344	1	5	3.81	.905
S3 Use AI in doing exercises	344	1	5	3.72	.952
S4 Use AI in completing assigned homework	344	1	5	3.60	.987
AI_LEVEL	344	1.00	5.00	3.8038	.78989
Valid N (listwise)	344				

Table 2. The AI Technology Usage

7.2 THE INFLUENCE OF ARTIFICIAL INTELLIGENCE TECHNOLOGY ON ENGLISH LANGUAGE COMPREHENSION LEVELS

The findings indicate that Artificial Intelligence (AI) technology has a positive influence on students' English language comprehension at Politeknik Kota Bharu across four key language domains: writing, reading, speaking, and listening. All domains recorded mean scores above 3.8, reflecting a generally positive perception of AI-supported language learning. However, the degree of improvement varied across skills, with writing and reading showing higher mean scores compared to speaking and listening.

One possible explanation for this variation is the nature of AI tools most frequently used by students. As the findings show, commonly used tools such as ChatGPT, Google Translate, and Grammarly are predominantly text-based and are designed to support reading comprehension, vocabulary development, and writing accuracy. These tools allow students to revisit content, revise outputs, and receive immediate corrective feedback, which may contribute to greater improvements in writing and reading skills compared to oral skills that require real-time interaction and pronunciation practice.

7.2.1 WRITING SKILLS

Students reported notable improvements in writing skills through the use of AI tools. Higher clarity and organization in writing recorded a mean score of 4.02, while improved word choice achieved a mean score of 4.12. Additionally, students indicated a reduction in grammatical errors (mean = 4.13) and an enhanced ability to write more professionally (mean = 3.99), resulting in an overall writing mean score of 4.07.

The strong improvement in writing skills may be attributed to the frequent use of AI tools that provide instant feedback on grammar, sentence structure, and vocabulary. The availability of automated suggestions and corrections enables students to refine their written work independently, reinforcing learning through repeated practice.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
S5 Produce clearer and more organized writing	344	1	5	4.02	.884
S6 Choose more appropriate words	344	1	5	4.12	.810
S7 Reduce mistakes in writing	344	1	5	4.13	.814
S8 Improves ability to write more professionally	344	1	5	3.99	.879
WRITING	344	1.00	5.00	4.0654	.76390
Valid N (listwise)	344				

Table 3. The Effects on Writing Skills

7.2.2 READING COMPREHENSION

AI tools were also effective in improving reading comprehension, with an overall mean score of 4.00. Students found it easier to understand articles or texts (mean = 3.89), comprehend new vocabulary (mean = 4.11), and interpret complex sentence structures (mean = 4.01). AI-assisted explanations and translations further supported students in analysing and interpreting content (mean = 4.03) and understanding overall text meaning (mean = 3.97).

The improvement in reading comprehension may be linked to students' reliance on AI tools to clarify meanings, paraphrase content, and provide contextual explanations, which are particularly beneficial for learners with limited language exposure. The ability to control reading pace and revisit explanations allows students to process information more effectively.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
S9 Makes it easier to understand articles or texts	344	1	5	3.89	.895
S10 Helps in understanding the meaning of new words	344	1	5	4.11	.845
S11 Helps in understanding more complex sentence structures	344	1	5	4.01	.849
S12 Helps in understanding the overall meaning of text better	344	1	5	3.97	.836
S13 Helps analyse and interpret content	344	1	5	4.03	.802
READING	344	1.00	5.00	4.0012	.74895
Valid N (listwise)	344				

Table 4. The Effects on Reading Comprehension

7.2.3 SPEAKING SKILLS

The findings show a positive but comparatively moderate impact of AI on speaking skills, with an overall mean score of 3.89. Students reported increased confidence in speaking English (mean = 3.85), improved pronunciation (mean = 3.96), reduced anxiety when speaking (mean = 3.78), and more frequent English practice (mean = 3.85).

The relatively lower improvement in speaking skills may be due to the limited use of AI tools that support interactive, real-time oral communication. Speaking proficiency often requires immediate feedback, spontaneous interaction, and sustained practice, which may not be fully supported by text-based AI tools commonly used by students.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
S14 Increases confidence to speak	344	1	5	3.85	.924
S15 Improves pronunciation	344	1	5	3.96	.890
S16 Reduces anxiety when speaking	344	1	5	3.78	.905
S17 Helps practice English more often	344	1	5	3.85	.855
S18 Helps in knowing the correct pronunciation of words	344	1	5	4.00	.866
SPEAKING	344	1.00	5.00	3.8884	.79538
Valid N (listwise)	344				

Table 5. The Effects on Speaking Skills

7.2.4 LISTENING PROFICIENCY

Listening proficiency also showed positive outcomes, with an overall mean score of 3.88. Students indicated improved understanding of conversations (mean = 3.93), better comprehension of different accents (mean = 3.79), and enhanced overall listening comprehension (mean = 3.92).

Similar to speaking skills, listening improvement may be influenced by the extent to which students engage with audio-based AI resources. While AI tools can support listening through generated audio or multimedia content, students may have fewer opportunities to practice listening skills independently compared to reading and writing, which are more commonly integrated into academic tasks.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
S19 Improves understanding of conversation	344	1	5	3.93	.829
S20 Helps in understanding English of various accents	344	1	5	3.79	.889
S21 Improves listening comprehension	344	1	5	3.92	.808
LISTENING	344	1.00	5.00	3.8828	.75773
Valid N (listwise)	344				

Table 6. The Effects on Listening Proficiency

Overall, the findings demonstrate that AI technology contributes positively to English language learning among students at Politeknik Kota Bharu. The higher gains observed in writing and reading suggest that AI tools are particularly effective in supporting text-based language skills, while improvements in speaking and listening may require more interactive and audio-focused AI applications. These findings provide important insights into how AI tools are currently used and where further instructional support may be needed to achieve balanced language development.

8. CONCLUSION

The findings of this study underscore the significant impact of Artificial Intelligence (AI) technology on teaching and learning processes, particularly in supporting English language comprehension among students at Politeknik Kota Bharu. AI has demonstrated strong potential in facilitating personalized and effective learning experiences by providing real-time feedback, supporting independent learning, and enhancing students' motivation and engagement.

As noted by Brown and Smith (2021), AI enables students to access learning resources tailored to their proficiency levels, thereby accelerating the learning process and improving comprehension outcomes.

Although the findings indicate that polytechnic students are actively engaging with AI tools, several barriers to broader and more effective adoption remain. One key challenge relates to lecturer readiness and digital competence. Lecturers play a critical role in guiding students' use of AI tools, and without sufficient training and pedagogical support, the integration of AI into teaching practices may remain limited or inconsistent. Furthermore, differences in students' access to technology and familiarity with AI applications may affect equitable participation in AI-supported learning.

In addition to implementation challenges, ethical considerations must also be addressed to ensure responsible use of AI in education. Issues related to data privacy, transparency, and potential bias in AI-generated content raise important concerns, particularly when students rely heavily on AI tools for learning and assessment. Educational institutions must therefore establish clear guidelines and ethical frameworks to safeguard students' data and promote critical and informed use of AI technologies. As emphasized by Kim and Park (2022), institutional support, infrastructure development, and continuous professional training are essential to maximize the benefits of AI while minimizing potential risks.

In conclusion, while AI has considerable potential to enhance inclusive, student-centred learning in TVET education, its effective integration requires coordinated efforts from educators, institutions, and policymakers. Introducing AI-focused or skill-based training modules, strengthening lecturers' digital competencies, and addressing ethical and infrastructural concerns are crucial steps toward sustainable implementation. Future research could explore longitudinal impacts of AI-assisted language learning, examine lecturers' readiness and perceptions of AI integration, or investigate policy frameworks that support ethical and effective AI adoption in Malaysian TVET institutions. Such efforts would contribute to the development of a more innovative, responsible, and globally competitive education system.

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11. AUTHORS' CONTRIBUTION

Melissa Khor Suan Chin led the conceptualisation, research design, data collection, and manuscript writing. She also coordinated the overall research process and interpretation of findings. Che' Fadhilah contributed to the development and validation of the research instrument, data analysis, and critical review of the manuscript. Rodey Hamza assisted in literature review, data entry, and formatting of research materials. All authors read and approved the final version of the paper.

12. CONFLICT OF INTEREST STATEMENT

We certify that the article is the Authors' and Co-Authors' original work. 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 IJELHE.

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Pre-University Students' Motivation and Online Learning Engagement: The Mediating Role of Attitude in using Generative AI Technology

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Abstract: *This research focuses on determining the motivational factors that influence online engagement among pre-university students. Based on the self-determination theory, the four motivational factors identified in this research include intrinsic and extrinsic motivation, accomplishment and amotivation. This research extends the framework to examining the mediating role of attitude to generative AI technology in the relationship between the four motivational factors with online learning engagement. Data from 103 respondents were collected online, demographic profiles were analyzed using SPSS, and Smart-PLS was used to test the conceptual model and assess item reliability through CFA. The results show five supported hypotheses, highlighting attitude and intrinsic motivation as key predictors of online learning engagement. Attitude has the strongest direct effect on online learning engagement, while intrinsic motivation influences both attitude and engagement. Indirect effects via attitude are significant for accomplishment, amotivation, and intrinsic motivation, indicating partial mediation. This study highlights the importance of using generative-AI tools in ensuring online learning engagement among pre-university students. Practical implications from this study include the need for training for academics and pre-university students to foster positive attitude towards using generative-AI technology.*

Keywords: *attitude, generative AI, motivation, online learning engagement, higher education*

1. INTRODUCTION

Online engagement refers to how individuals interact with digital content or platforms over the internet. In the context of education, it refers to how actively and effectively students participate in digital learning environments. It reflects students' interaction with the course content, their peers and instructors through online platforms (Hossain et al, 2022). On a similar but more meaningful term in the context of effective learning, online learning engagement (OLE) studies the depth and quality of student involvement with learning itself which includes deep thinking and reflection on the subject matter (Bergdahl, 2022; Hu and Xiao, 2025). The widespread use of online learning can be attributed to the quick uptake of computer-assisted learning and educational technologies. Generative Artificial Intelligence (Gen-AI) technologies such as ChatGPT, Grammarly and Quizlet have rapidly transformed the landscape of higher education. While these tools offer new possibilities for academic support in enhancing teaching and learning, it is critical to understand the motivational drivers influencing students' online learning engagement.

Many studies have offered promising results on factors influencing online engagement in learning, focusing mostly among undergraduate students (Ferrer et al., 2022, Bedi, 2023). This study, nonetheless, focused on pre-university students, addressing the notable lack of representation as highlighted in Hu and Xiao (2025). In Malaysia, for instance, students complete six years of primary education and five years of secondary education and relied predominantly on rote learning during their eleven years of school (Ani et.al., 2024). Furthermore, facing the challenge of relatively few attempts to use the self-determination theory (Hu and Xiao, 2025), this study adapts the framework of Ferrer et al. (2020), addressing the attitude of students toward generative artificial intelligence tools as a mediator to OLE. Moreover, while generative artificial intelligence (Gen-AI) tools are increasingly integrated into educational settings, little is known about how pre-university students' attitudes toward Gen-AI influence their online learning engagement. This gap highlights the need to examine Gen-AI mediated engagement specifically in pre-university learners, addressing both their motivational profiles and their attitude to adopt AI-enhanced learning tools.

1.1 RESEARCH OBJECTIVES

The dual purpose of this study is to firstly determine the motivational factors that influence OLE among pre-university students. Grounded in self-determination theory, this study focuses on four key motivational factors namely intrinsic and extrinsic motivation, accomplishment and amotivation. Following this, this study extends this framework by examining the mediating role of students' attitude on using Gen-AI tools between motivational factors and online learning engagement.

1.2 LITERATURE REVIEW

Engagement reflects students' level of involvement, interest, or devotion to a specific activity, mission, or relationship. The level of student engagement is measured by how actively and enthusiastically students are involved in academic, curricular, and extracurricular activities (Hossain et al., 2022), including the level of curiosity, initiative, and participation that students put into their learning experience. Educational achievement, personal motivation, and emotional commitment are strongly linked to students' engagement (Acosta-Gonzaga, 2023). For this reason, when the learning context becomes compelling, students are truly engaged and often perform better in school and develop a lasting passion for learning. However, learning can be challenging for students due to a lack of peer connection and technological concerns for online classes, which may impact students' interest and engagement (Hollister et al., 2022). Digital platforms make education more accessible and convenient by providing greater freedom of access, lower education prices, flexibility, adaptability to modern life, as well as the ability to divide content into modules and define assessment criteria (Liu et al., 2020). In contrast to this finding, students appeared to suffer even more with participation in online classes, even when expected grades increased; lecture attention, attendance, and perceived ability to keep up with schoolwork all decreased significantly (Hollister et al., 2022). To organize these insights systematically, this review is divided into two key themes: motivational factors and attitudes.

1.2.1 STUDENTS' MOTIVATIONAL FACTORS

The four motivational factors identified based on Ryan and Deci (2000a) are accomplishment, amotivation, extrinsic and intrinsic motivation.

Accomplishment refers to one's ability to successfully complete a task, aim, or objective. Students' accomplishments are varied, viewed in many ways, such as academic efficacy and competence, positive academic self-concept, and self-assessment of completing a task (Hossain et al., 2022). Another related study by Taip et al. (2023), found that increasing online learning methods led to improved students' commitment and academic success. These findings contradicted the worry that online learning could negatively impact students' dedication and academic achievement. Similarly, another study postulated a positive and significant association between academic success and online learning platforms (Abuhassna et al., 2020).

Amotivation is a situation where an individual is uninspired or disinterested in engaging in a particular activity (Ryan and Deci, 2000a). It represents a feeling of being uncommitted towards the task, unfocused, and lose purpose to take action to learn. Students who reported more amotivation had lower GPAs, a lower level of match in the college, and a lower level of self-reported college adjustment (Norvilitis et al., 2022). Amotivated students may feel disconnected from school or academic work. As a result, they may experience a lack of effort in completing individual and group assessments, poor attendance, poor exam performance, and disengagement during the learning process, as they might not see the aim or purpose in their education or have low self-efficacy. Kotera et al. (2021), for instance, found that amotivation was favorably connected with inadequate and loathed self, while negatively associated with intrinsic motivation, energy, dedication, absorption, and comforted self.

Extrinsic motivation focuses on external outcomes, which indirectly influence someone's actions. For example, a student studies hard on a task to receive a good grade or to avoid feelings of shame or self-criticism rather than doing it because they find the task intrinsically interesting and enjoyable. According to Bakar et al. (2022), there is a strong positive relationship between extrinsic motivation, such as academic grades and academic achievements, among undergraduates. In general, students' motivation enhances their academic performance and serves as an excellent predictor of students' academic advancement.

According to Gustiani et al. (2022), students' participation in online learning due was due to their autonomy or self-determination over the regulations of online learning. They attended their online class merely to avoid awkwardness and penalties for being absent as a method of self-regulation. Some of them participated in online learning activities because they perceived them as values that aligned with one of their life goals. Most participants in online classes are driven by extrinsic factors such as the prohibition of absenteeism and grades (Mansour et al. (2021).

Intrinsic motivation is the drive to engage in an activity because it is enjoyable, interesting, or personally meaningful, rather than for external rewards or outcomes. Key factors for pleasurable and successful learning include interest in material, relevance to the profession and life, good instruction, and interactive pedagogies (Seemiller et al., 2021). Intrinsic motivation is often linked to better engagement and long-term satisfaction in the learning activities, as it could develop students into a deeper sense of fulfillment and personal growth. A notable study by Fishbach et al. (2021), linked intrinsic motivation with a lack of rewards. Rewards have a beneficial impact on two intrinsic motivators, such as involvement during free choice and self-reported good experiences. Rewarding a task increases both people's desire to perform the task. Students who received need-supportive task instructions from teachers showed better intrinsic motivation (Mendoza et al., 2023). This finding implies that while intrinsic motivation for the task does not always result in enhanced task performance, it might directly improve online task performance through self-assessment practice as a behavioral learning method. The next section discusses attitudes toward Gen AI tools.

1.2.2 ATTITUDE

Attitude refers to a person's consistent way of thinking or feeling about someone or something, which is generally reflected in their actions. Attitude is a mindset that shapes how we perceive and react to situations, which is rooted in someone's personal views and emotions. Attitude can be the foundation of habit formation; changes can be a useful beginning point for behavior modification (Verplank and Orbell, 2022). A person's attitude towards AI may be influenced by their perception of their own learning (Sindermann et al., 2020).

Researchers examine how attitude influences perceived ease of use and students' intention to use online learning platforms in Malaysian distance learning and found that attitudes play a role in regulating the association between perceived ease of use and intention in online distance learning institutions. From an academician perspective, the analysis found that attitude towards distance education plays a complete mediation role in the effect of digital literacy level on course teaching satisfaction, but only partially in the effect of digital literacy level on satisfaction with infrastructure (Sever and Cati, 2021). This discovery enables institutions to create high-quality online platforms that benefit students.

Drawing from the established connections between students' motivation, online learning engagement and attitude on using Gen-AI tools identified in the previous studies, Figure 1 illustrates the conceptual framework:

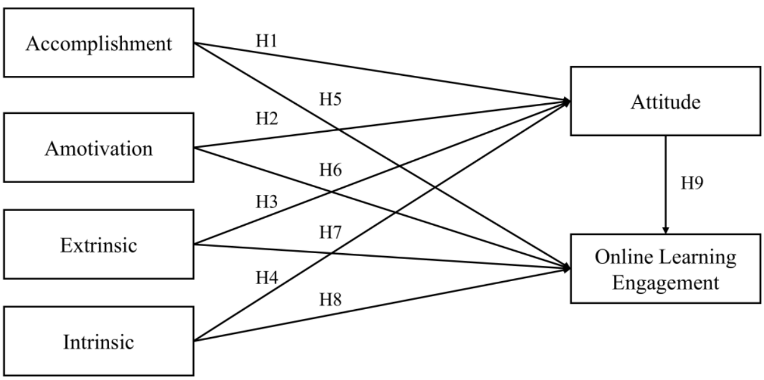

Figure 1: Proposed Conceptual Framework.

Overall, previous studies have highlighted several key factors involving four key motivational factors namely intrinsic and extrinsic motivation, accomplishment and amotivation together with examining the mediating role of students' attitude on using Gen-AI tools between motivational factors and online learning engagement. Therefore, the next section outlines the methodology used to empirically test this relationship.

2. METHODOLOGY

2.1 SAMPLE

To examine the proposed relationship within the context of the previously outlined theoretical framework, Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed. PLS-SEM was used because the study focuses on predicting how motivational factors influence online learning engagement (OLE) among pre-university students. It is suitable for exploratory research, works well with smaller samples and non-normal data, and handles complex models better than CB-SEM, which requires larger samples and is mainly used for theory confirmation. An additional sampling criterion for PLS-SEM, known as the "ten times rule," requires that the sample size be at least ten times greater than the highest number of paths in either the formative or structural measurement models (Chin, 1998; Hair et al., 2021). Consequently, the study's sample size of 103 participants was deemed adequate and dependable for the analysis.

The study employed purposive sampling to recruit participants who met the specific criterion of being pre-university students. This approach ensured that the sample was aligned with the study's objective to examine motivational factors that influence OLE among pre-university students.

2.2 RESEARCH DESIGN

In this study, a modified questionnaire was utilized to evaluate the relationships between variables. This study adapts Ferrer et al.'s (2020) framework, extending it to examine students' attitudes toward generative AI tools as a mediator influencing Online Learning Engagement (OLE). Motivation constructs- accomplishment motivation, amotivation, intrinsic motivation, and extrinsic motivation were measured using the Academic Motivation Scale (Vallerand et al., 1992). Attitudes toward online learning were measured using Davis's Technology Acceptance Model (1989), while the mediator construct was operationalized through items adapted from recent studies on AI acceptance in education. All constructs were assessed on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) to ensure reliability and consistency across measures.

This study received ethical approval from the institutional ethics committee. Participants were informed about the study purpose, confidentiality, and voluntary participation, and were provided electronic informed consent before completing the questionnaire.

2.3 DATA ANALYSIS

The researchers successfully obtained 103 fully complete questionnaires from their online data collection efforts. The study employed SPSS and Smart-PLS for data analysis. The reliability of individual items was assessed through confirmatory factor analysis (CFA).

3. RESULTS

Demographic Profile
The demographic data represents a total of 103 respondents. Most participants are 18 years old (71.8%), followed by 17-year-olds (9.7%) and 19-year-olds (7.8%). The sample includes a small number of respondents aged 16, 21, 20, and 23, each constituting less than 4% of the total. In terms of gender, 58.3% are female, while 41.7% are male. Ethnic distribution is led by Chinese participants, who make up 64.1% of the group, followed by Malays at 11.7%, Indians at 1.0%, and others at 23.3%. Regarding academic programs, most respondents (62.1%) are enrolled in the Foundation in Business program. Foundation in Arts accounts for 35.9%, and only 1.0% are in Foundation in Science. When it comes to experience with AI technology, more than half of the respondents (53.4%) have used AI for less than one year. About a third (33.0%) have 1–3 years of experience, and 13.6% have more than three years of experience.

Model assessment using PLS-SEM
The measurement model in this study was evaluated using reflective indicator metrics, in line with PLS-SEM procedures. Reliability was first confirmed through Cronbach's Alpha and Composite Reliability (CR), with all constructs exceeding the recommended threshold of 0.7, indicating strong internal

consistency (Ab Hamid et al., 2017; Sarstedt, 2019). For instance, the CR values ranged from 0.804 (OLE) to 0.932 (Extrinsic). Convergent validity was assessed using Average Variance Extracted (AVE). All constructs achieved AVE values above the 0.5 threshold, supporting sufficient convergent validity (Hair Jr. et al., 2021). Such constructs include Accomplishment (AVE = 0.776) and Intrinsic Motivation (AVE = 0.658). Indicator reliability was confirmed as most item loadings exceeded 0.7. Although a few loadings (e.g., ATT5 = 0.602) were slightly below the ideal, they were retained due to theoretical relevance and overall model fit. These results demonstrate that the measurement model is reliable and valid, and suitable for structural path analysis.

Heterotrait-Monotrait (HTMT) ratio values among six constructs: Accomplishment, Amotivation, Attitude, OLE, Extrinsic, and Intrinsic are below the conservative threshold of 0.85 (Henseler et al., 2015). Overall, the constructs demonstrate acceptable levels of distinction for further structural modeling.

Structural Model Analysis

The path coefficients for the modelled relationships between the constructs are generated by PLS as shown in figure 2. The predictive power R2 and predictive relevance were used to evaluate the model's ability to predict the outcome variables (Hair et al., 2021). R-Square levels of 0.67, 0.33, and 0.19 are considered strong, moderate, and weak, respectively. The R-squared values of the endogenous latent variables Attitude and Online Learning Engagements are 59.3% and 56.5% respectively, indicating a moderate level of model fitness for both variables.

Table 1 summarizes the hypothesis testing results for the structural model analyzing relationships between variables such as Accomplishment, Amotivation, Intrinsic and Extrinsic motivation, Attitude, and OLE (Online Learning Engagement). Out of the nine proposed hypotheses, five are supported based on significant p-values (< 0.05). Specifically, H3 (Extrinsic -> Attitude), H4 (Intrinsic -> Attitude), H6 (Amotivation -> OLE), H8 (Intrinsic -> OLE), and H9 (Attitude -> OLE) show significant relationships, indicating these paths have meaningful influence on their respective dependent variables.

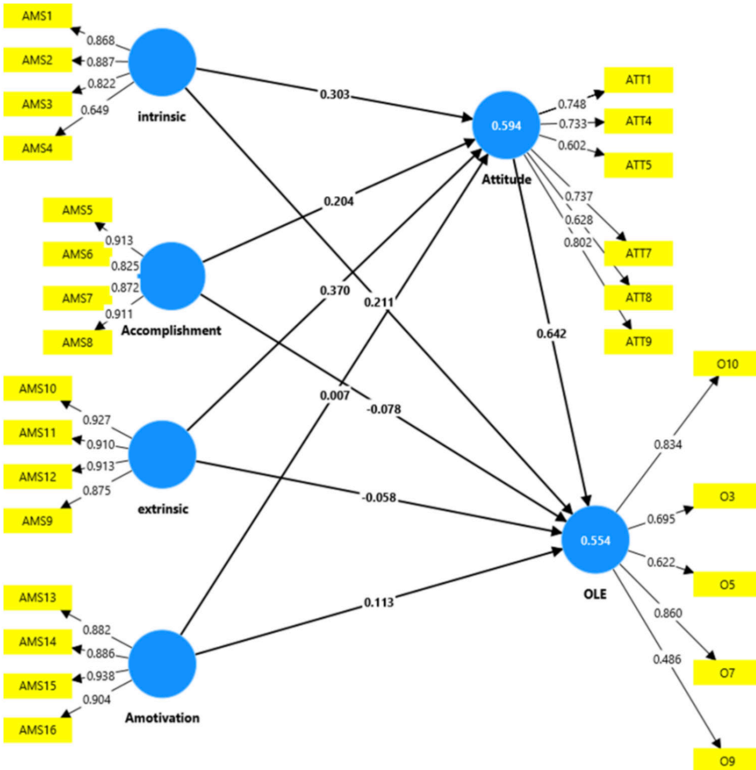

Figure 2. Path Coefficients

The strongest influence is observed in H9, where Attitude significantly predicts OLE (β = 0.659, p = 0.000), suggesting that a positive attitude greatly enhances students' engagement in online learning. Intrinsic motivation is also a consistent predictor of both Attitude (H4: β = 0.308, p = 0.003) and OLE (H8: β = 0.175, p = 0.006), emphasizing the importance of internal drivers in learning contexts. Conversely, H1, H2, H5, and H7 are not supported, implying that Accomplishment and Extrinsic motivation do not significantly influence Attitude or OLE in this model.

Hypothesis	Path	Beta	T-statistic	P-value	Decision
H1	Accomplishment -> Attitude	0.201	1.871	0.061	Not Supported
H2	Amotivation -> Attitude	0.008	0.125	0.900	Not Supported
H3	Extrinsic -> Attitude	0.369	3.532	0.000	Supported
H4	Intrinsic -> Attitude	0.308	3.023	0.003	Supported
H5	Accomplishment -> OLE	0.085	0.738	0.461	Not Supported
H6	Amotivation -> OLE	0.154	3.619	0.006	Supported
H7	Extrinsic -> OLE	0.054	0.444	0.657	Not Supported
H8	Intrinsic -> OLE	0.175	2.591	0.006	Supported
H9	Attitude -> OLE	0.659	7.418	0.000	Supported

Table 1. Direct relationship

Table 2 presents the results of indirect relationships between motivational factors (Accomplishment, Amotivation, Extrinsic, and Intrinsic) and Online Learning Engagement (OLE) through the mediating variable "Attitude." The strength and significance of these relationships are assessed using Beta values, T-statistics, and P-values. The analysis reveals that both Accomplishment ($\beta = 0.132$, $T = 1.786$, $p > 0.001$) and Amotivation ($\beta = 0.005$, $T = 0.122$, $p > 0.05$) have significant indirect effects on OLE via Attitude. However, their associated hypotheses (H1a and H2a) are marked as rejected, which might imply these effects contradict theoretical expectations, or direct paths were not significant in a broader model context. In contrast, the path from Extrinsic motivation to OLE via Attitude ($\beta = 0.243$, $T = 3.067$, $p < 0.05$) is not statistically significant, yet the result states it "Fully Mediates," possibly suggesting that the direct path was non-significant, and only the indirect effect exists. The Intrinsic path ($\beta = 0.203$, $T = 2.692$, $p < 0.05$) is significant and thus considered to "Partially Mediate" the relationship with OLE.

Hypothesis	Path	Beta	T-statistic	P-value	Result
H1a	Accomplishment -> Attitude -> OLE	0.132	1.786	0.074	Rejected
H2a	Amotivation -> Attitude -> OLE	0.005	0.122	0.903	Rejected
H3a	Extrinsic -> Attitude -> OLE	0.243	3.067	0.002	Fully Mediate
H4a	Intrinsic -> Attitude -> OLE	0.203	2.692	0.007	Partially Mediate

Table 2. Indirect relationship

4. DISCUSSION

The primary goal of this study is to identify the motivating factors that influence pre-university students' engagement on online learning. The self-determination theory provides a valuable lens for examining the motivational factors underlying students' adoption and use of Gen-AI tools in online learning. This study examines four major motivational factors: amotivation, accomplishment, intrinsic and extrinsic motivation. We expand the framework in investigating the mediating role of attitude toward using Gen-AI tools between motivational factors and online learning engagement. From the four motivational factors identified, intrinsic motivation and amotivation are found to significantly influence OLE. Intrinsic motivation significantly influences OLE, similar to the study of Wang (2022) and Aruğaslan et al. (2025), suggesting that intrinsically motivated students are self-determined in ensuring learning takes place effectively. Secondly, amotivation significantly influenced students' engagement on online learning, suggesting that unmotivated students are unable to engage in their online learning. In line with Ferrer et al. (2020) and He and Ong (2025), amotivated students typically find themselves unable to control or are incompetent, leading to the inability to understand the connection between their actions and learning outcomes.

Nonetheless, the importance of accomplishment cannot be overlooked. Our findings imply the need to strengthen students' confidence, as existing research demonstrates its substantial influence in students' attitude towards online learning (Hossain et al., 2023, Taip et al, 2023). Similarly, the non-significant influence of amotivation on attitudes toward online learning may be attributed to low levels of amotivation reported by students (Rosli et al., 2022). Another possibility is that students were already sufficiently supported or engaged, thereby reducing the impact of amotivation on their attitude towards online learning.

Secondly, with regards to the mediation role of attitude of the pre-university students in using Gen-AI technology, this study found that attitude fully mediates the relationship between extrinsic motivation with OLE and partially mediates the relationship between intrinsic motivation and OLE. External rewards such as obtaining good grades were found to motivate students to engage in online learning, via attitude towards Gen-AI technology. Previous studies such as those conducted by He and Ong (2025), Akram and Li (2024), and Ryan and Deci (2020b) confirmed extrinsically motivated students are stimulated to engage in online learning - for instance, using public or virtual recognition of their achievement which encourages opportunities for them to showcase their work. This study, however, found that the relationship is only mediated through their mindset in using Gen-AI tools. Additionally, this study confirms that intrinsic motivation does not directly influence OLE but can be enhanced through their attitude in using Gen-AI. This finding deepens our understanding of how attitude in using Gen-AI platforms impacts students' engagement in online learning. While this study contradicts the findings of Ferrer et al. (2020), this result serves as new insights in understanding how online engagement improves among Generation Z students.

This study is limited by its focus on pre-university students within a specific educational context, which may restrict the generalizability of its findings to other student populations. The reliance on self-reported data may introduce bias, particularly in assessing motivation and attitudes toward Gen-AI tools. Additionally, cross-sectional design prevents causal inferences between motivational factors, attitudes, and online learning engagement. While the mediation role of attitude was explored, other potential mediators or moderators such as digital literacy or prior experience with Gen-AI were not examined. Future studies should adopt longitudinal designs and consider a broader range of variables and student demographics.

5. CONCLUSION

This study significantly advances our understanding of factors influencing online learning engagement among pre-university students. The findings indicate that the more amotivated the students are, the lower their engagement in online learning. Next, intrinsically motivated students not only influence OLE directly, but also influence OLE through their attitude in using Gen-AI tools. While extrinsic motivation does not significantly influence OLE directly, extrinsic motivation influenced OLE through their attitude on using Gen-AI tools. These findings suggest that policymakers should encourage intrinsic motivation and include Gen-AI tools in pre-university curricula, while educators can boost engagement by promoting positive attitudes toward Gen-AI and addressing sources of amotivation to reduce disengagement.

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8. AUTHORS' CONTRIBUTION

Abd.Ghani, H. and M.Ibrahim, H. designed and organized the experiments. M.Ibrahim, H. conducted the experiments and prepared the data. M.Ibrahim, H. contributed to the analysis of the results. Abd.Rahman, R. led the writing of the manuscript. All authors offered valuable feedback and contributed to shaping the research, analysis, and manuscript.

9. CONFLICT OF INTEREST DECLARATION

We certify that the article is the authors' and co-authors' original work. 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 IJELHE.

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The Acquisition of Psychomotor Skills Through Scientific Instrumentation Andragogical Approach in Learning Style

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Abstract: *This study investigated the impact of the Scientific Instrumentation Andragogical Approach (SIAA) on the development of tertiary students' psychomotor skills, using experiential and self-directed laboratory learning. A total of 135 Applied Sciences students at Universiti Teknologi MARA, Shah Alam completed validated questionnaires. Reliability analysis yielded excellent internal consistency of the Practical Skill Acquisition (0.938), Student-Centered Learning (0.932), and Skill Application & Future Preparedness (0.898). Correlations r between 0.694 – 0.749 demonstrated strong construct coherence. Although data significantly departed from perfect normality, skewness and kurtosis that were within ± 2 validated reasonable interpretation. Results substantiated high self-efficacy and readiness for real- world application. Compared to the other dimensions, skill applicability had the strongest influence. The SIAA effectively boosted students' psychomotor competence, autonomy, and reflectiveness of the learning style. In application, the approach is consistent with adult learning andragogy and aligns the laboratory practice with employability-focused higher-education outcomes.*

Keywords: *Andragogy, Experiential learning, Higher education Psychomotor skills, Reliability, Scientific instrumentation*

1. INTRODUCTION

One of the key objectives of science, technology, engineering, and mathematics (STEM) educational system is the development of psychomotor skills. This is particularly true for laboratory-based courses in which students must acquire the ability to convert theory into exact practical performance (Dave, 1970; Simpson, 1972). Psychomotor skilling involves the use of instruments and tools, as well as related metacognitive habits of planning, monitoring, and adjusting the partner skilled action (Adams, 1989).

However, most laboratory-learning methods are teacher-centered, process-driven modes that favor repetition and procedural correctness over learner autonomy, reflection, and contextual problem solving (Biggs & Tang, 2011). Such traditional approaches may not be optimal to scaffold independent psychomotor mastery or transferable technical competence (Nikolić, 2024). Malcom Knowles' andragogical theory posits that effective adult learning experiences prioritize motivation, problem- centered training tasks, and prompt application (Knowles, 1984; Kanapathy, 2023). In the last few years, several scholars have shown that adult learning theory-informed instruction strategies correlate positively with student engagement, self-efficacy, and transfer of learning in higher education (Livingston, 2023; Sánchez-Domenech, 2024).

This convergence is brought together to form a learning design, a new instructional paradigm called Scientific Instrumentation Andragogical Approach (SIAA). With this SIAA learning design pattern, learners participate in instrument-based laboratory activities that are autonomously designed and utilized for reflection and the solving of real-world problems. This has been inspired by experiential educational theories (Kolb, 2015; Kolb & Kolb, 2018) as well as recent innovations that draw on hands-on, constructive exposure in genuine settings and authentic scaffolding (Konidari, 2022). This trend has been fueled by the development of remote, online, and mixed laboratory andrologies, which have been growing in importance compared to psychomotor learning. As a result, the general andragogical activities provided must be extra learner-centered in the instrumentation studies (Isa, 2024).

However, there is minimal empirical proof that andragogical architecture equated to the psychomotor outcomes in instrument-rich laboratory-based cultures. Several studies have addressed results in cognitive or affective fields, while other works have concentrated on laboratories of overall content rather than instrumentation-intensive courses (Yuliani, 2024; Hamidani et al., 2025). Hence, the examination seeks to verify how the SIAA contributes to psychomotor skills development among undergraduate scholars in the Faculty of Applied Sciences by the method of a checked self-assessment device.

Based on the integration of the adult learning theory, psychomotor domain taxonomy, and instrumentation andragogy as shown in Figure 1, this research intends to contribute to two aspects: one is validating a measurement tool for psychomotor skill acquisition in higher education and the other aspect is proving the andragogical laboratory design on enhancing learner's level of psychomotor competence and confidence and readiness for professional practice.

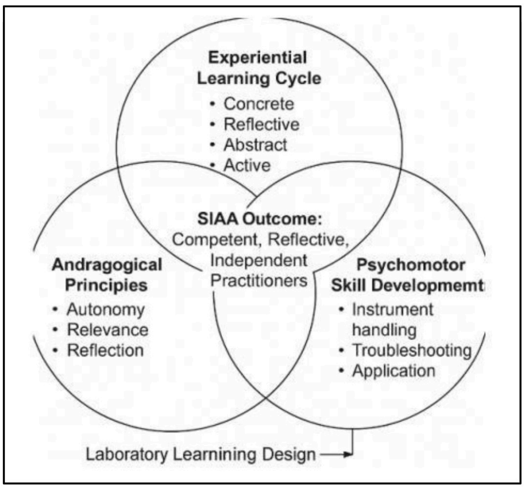

Figure 1. Integration of andragogy, experiential learning, and psychomotor skill development in Instrumentation-rich laboratories.

2. METHODOLOGY

2.1 RESEARCH DESIGN AND PARTICIPANTS

A quantitative descriptive design was adopted in this study. The participants were 135 Faculty of Applied Sciences students enrolled in 5 programs Materials Science Technology, Physics/Physics Industry, Food Technology, Polymer Technology and Chemistry/Environment program at Faculty of Applied Sciences, Universiti Teknologi MARA. These students had completed practical laboratory courses which emphasized the instrumentation and processing methods. Demographically, the cohort represented a diverse mix of gender, academic performance, and prior exposure to laboratory work.

2.2 INSTRUMENTATION

A structured instrumentation of Likert-scale questionnaire (1=Strongly Disagree to 5=Strongly Agree) was developed to assess the technical and instrumentation proficiency, application of theory to practice, problem-solving and troubleshooting, reflective and independent learning, as well as confidence and readiness for real-world applications.

2.3 PROCEDURE

The questionnaire was distributed electronically using Google Forms after the students had completed the laboratory sessions in March-August 2025 of the academic session. The data collection process spanned two weeks, in which students were encouraged to reflect on their experiences before completing the instrument.

2.4 DATA ANALYSIS

The analysis of the data was conducted using IBM SPSS Statistics (Version 26). The statistical procedures applied include the reliability analysis used to determine internal consistency and measure using Cronbach's alpha. Item-Total Correlation was performed for constructing validity of the data. Each item's contribution to overall reliability was assessed. The results are used to confirm the construction validity and coherence of the instrument. The normality test was employed to assess data distribution across all Likert-scale items. The p-value should be >0.05 to indicate the normality. Therefore, normality tests determined either parametric or non-parametric interpretations of the data. The descriptive and visual analysis were presented through histogram and correlation heatmaps of the response pattern.

3. PROBLEM STATEMENT

Despite the increasing emphasis on laboratory-based learning in higher education, many of the STEM programs still adopt teacher-centered and procedural approaches that prioritize rote experimentation over reflective, autonomous, and contextually relevant skill development. This process often made students be less prone to applying theoretical knowledge to practical demonstrations, which compromised systemic psychomotor competence, which subsequently leaves them unprepared for professional full-time work. Although andragogical principles including self-direction, reflection, and experiential engagement have been identified as efficacious of adult learning, an empirical linkage between andragogical design of the laboratory and quantifiable psychomotor outcomes is lacking. Therefore, there is a necessity to explore whether psychomotor skills can be enhanced, self-efficacy developed, or readiness for technical and professional task improved through an andragogy-based instructional model, namely the Scientific Instrumentation Andragogical Approach.

4. OBJECTIVES

The aim of this study is to examine the effectiveness of the Scientific Instrumentation Andragogical Approach (SIAA) in enhancing undergraduate students' psychomotor skills within laboratory-based learning environments. The objectives of this study are.

1. **To assess** the reliability and internal consistency of the SIAA psychomotor skill measurement instrument through Cronbach's Alpha and item-total correlation analysis.

2. **To examine** the normality and distribution patterns of students' responses toward the SIAA-based laboratory learning environment.

3. **To determine** the inter-construct correlations between Practical Skill Acquisition, Student- Centered Learning Experience, and Skill Application & Future Preparedness and establish construct coherence and theoretical alignment.

4. **To evaluate** students' self-efficacy, readiness, and perceived applicability of technical and psychomotor skills acquired through the SIAA laboratory experience.

5. RESULT AND DISCUSSION

5.1 RELIABILITY ANALYSIS

Reliability analysis was conducted using Cronbach's Alpha to determine the internal consistency of the item's constructs. The results demonstrated strong reliability across all dimensions as tabulated in Table

1. According to the previous studies (Hair et al. 2019), Cronbach's Alpha coefficient values demonstrate the items that measured the constructs with high precision and stability. From this study, the values obtained above 0.70 are acceptable and values over 0.90 indicate excellent internal consistency. Hence, all the three constructs exhibit strong internal reliability showing that the items in the instrument have cohesively measured the three constructions' underlying dimensions.

Construct	Number of Items	Cronbach's Alpha	Interpretation
Practical Skill Acquisition	9	0.938	Excellent reliability
Student-Centered Learning Experience	8	0.932	Excellent reliability
Skill Application and Future Preparedness	4	0.898	Good reliability

Table 1. Reliability Statistics for Major Constructs

The high reliability across constructs of Practical Skill Acquisition; α=0.938; Student-Centered Learning Experience; α = 0.932; and the Skill Application & Future Preparedness; α=0.898, indicate the respondents consistently understood and responded to the related psychomotor and experiential learning items. Reliable coefficients of comparable values have been reported by studies that examined laboratory-based competency development and self-efficacy surrounding the practical learning environment (Rahmat et al. 2022; Nguyen & Habib 2023).

5.2 NORMALITY ANALYSIS

This test was performed to check normality in the distribution of responses in the Likert-scale items. Normality tests were assessed using Kolmogorov–Smirnov and Shapiro–Wilk tests and tabulated in Table 2. Although the normality results indicated significant deviations from normality ($p < 0.05$), the skewness and kurtosis values were within ±2, which are acceptable for parametric analysis in samples larger than 100 (Tabachnick & Fidell, 2019). Therefore, the data distribution was considered almost normal for further analysis.

Variable	Kolmogorov–Smirnov (Sig.)	Shapiro–Wilk (Sig.)	Skewness	Kurtosis	Normality Interpretation
Practical	0.003	0.001	-0.049	-0.690	Not normal but approximately symmetric
Application	<0.001	<0.001	-0.389	1.163	Not normal; mild left skew
Student	<0.001	<0.001	-0.952	2.535	Not normal; moderate left skew

Table 2. Normality Test Results for Core Constructs.

5.3 INTER-CORRELATION CONSTRUCT AND THEORETICAL ALIGNMENT

The correlation matrix among constructs demonstrated strong positive relationships as presented in Inter-correlation heatmap in Figure 2. It can be observed that a strong set of correlations was collected from the inter-item matrix between all the questionnaire items in standardized form, most commonly of coherence reaching $r > 0.70$.

The correlations (r =0.694–0.749) indicate a strong positive relationship among the constructs: these represent a higher level of student-centered learning, and practical skill acquisition are associated with stronger readiness and application of skills in real-world contexts, thus supporting the theoretical coherence of the instrument's dimensional structure. This indicates a highly cohesive structure, showing a high- unity grant, making psychomotor-related items, such as instrument-manipulation, procedural safety, and practical application, closely united with cognitive and affective domains of confidence and reflective feedback; Practical Skill Acquisition ↔ Student-Centered Learning Experience ($r=0.75$, $p<0.01$), Student-Centered Learning Experience ↔ Skill Application and Future Preparedness ($r=0.72$, $p<0.01$) while Practical Skill Acquisition ↔ Skill Application and Future Preparedness ($r = 0.7$, $p <$
$.01$).

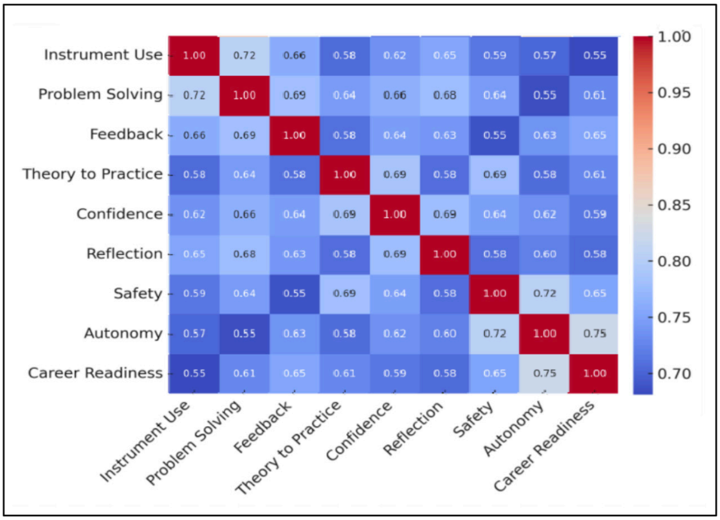

Figure 2. The Inter-Item Correlation Heatmap for the Practical Skill Acquisition

This high degree of correlation among items indicates a unidimensional yet multifaceted construct, representing the comprehensive nature of psychomotor learning in scientific contexts. As indicated by Kolb & Kolb (2018), learning in practical domains is not merely mechanical but also involves cognitive integration and reflective engagement and become evident in the observed inter-item relationships. The results echo the conceptual model of experiential learning theory (Kolb, 2015) and competency-based education frameworks

(Biggs & Tang, 2011), emphasizing iterative cycles of doing, reflecting, and applying. Hence, students who perceived their learning environment as interactive and supportive demonstrated greater readiness to apply their skills to real-world contexts. This coherence aligns with recent studies reporting that active engagement, instructor feedback, and resource adequacy are significant predictors of transferable skill confidence (Lee & Kato, 2023; Rafiq et al., 2022).

The consistent correlation pattern suggests that the SIAA successfully integrates psychomotor, cognitive, and affective dimensions into a cohesive learning experience. Students do not perceive these components as separate but as mutually reinforcing, which supports the theoretical stance that effective laboratory education must intertwine the technical skills with cognitive reasoning and emotional engagement.

5.4 SELF-EFFICACY READINESS AND PERCEIVED APPLICABILITY

From the histogram visualization depicted in Figure 3, it can be observed that all constructs showed a very minor left-skewed pattern, indicating that most of the respondents reported positive perceptions toward their learning experiences and psychomotor development in most of the items.

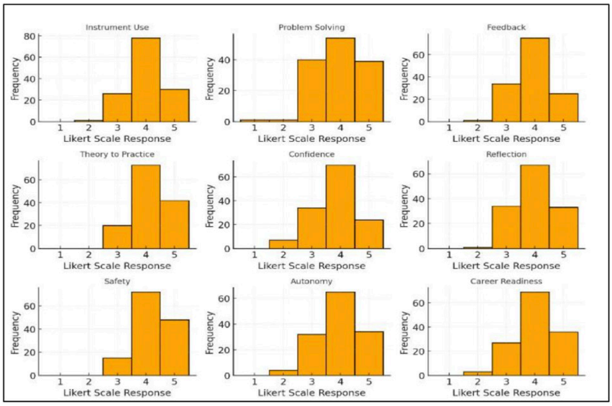

Figure 3. Distribution of student responses across nine psychomotor skill dimensions measured in the Scientific Instrumentation Andragogical Approach (SIAA) instrument.

This pattern is broadly in line with the findings of previous laboratory-based learning studies for students due to the high level of self-perceived competence and satisfaction with the guided, hands-on and problem-solving types of pedagogies for students (Hidayah et al., 2021; Zainuddin et al., 2022). Skewness is a key indicator of a frequent source of bias in self-evaluation research especially when participants perceive instruction as effective or when the learning experience aligns with their preferred cognitive and behavioral styles.

Furthermore, the left-skewed response patterns are especially pronounced in what concerns positive affective learning outcomes, which is a well-known feature of adult learning environments elucidated in multiple studies (Merriam et al., 2007). Encouraged by an andragogical environment and autonomous, contextual problem-solving opportunities, the learners naturally lean towards a more favorable assessment because they see value in what they are doing and its immediate practical use.

6. CONCLUSION

In conclusion, this study provided evidence of the SIAA being an effective method of improving students' psychomotor skills in the laboratory. The reliability results indicated high internal consistency across the constructs, ranging from 0.898 to 0.938. High inter-construct correlations, ranging from 0.69 to 0.75, suggested good theoretical coherence of the measures. The data was non-normally distributed although the similarity in patterns indicated high levels of learner engagement experiencing a high level of comfort with incorporating the taught skills in practice. The results of this study confirm the efficacy of andragogy-based laboratory teaching in promoting self-regulated learning behaviors, technical

proficiency, and professional competence. The SIAA method shows significant future potential in the promotion of school-based, competency-aligned STEM education and further research into the measurement of skill transfer and employability.

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9. AUTHORS' CONTRIBUTION

The author's contribution involved Suzana Ratim who analysed the data and writing the manuscript, Rosnah Zakaria and Maryam Husin designed and organized the experiments while Norazura Ibrahim and Rabiatuladawiyah Md Akhir are also contributed to the writing of the manuscript. All authors offered valuable feedback and contributed to shaping the research, analysis and manuscript.

10. CONFLICT OF INTEREST DECLARATION

We certify that the article is the authors' and co-authors' original work. 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 IJELHE.

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The Role of Technology in Shaping Online Learning Effectiveness in Engineering Higher Education: A Theoretical Perspective

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Abstract: *The digitization of engineering education is reshaping the design, delivery, and effectiveness of online learning environments. This conceptual paper examines how emerging educational technologies—such as artificial intelligence, immersive technologies, learning analytics, and cloud-based platforms—can be systematically integrated to enhance learning effectiveness in online engineering education. Drawing on an integrative review of contemporary literature and established learning theories, the study proposes a multidimensional framework comprising five interrelated dimensions: technological infrastructure, pedagogical design, user experience design, feedback and learning analytics, and support systems. Grounded in constructivism, connectivism, cognitive load theory, self-determination theory, and activity theory, the framework explains how coordinated technological and pedagogical alignment can improve learner engagement, motivation, collaboration, and performance. By moving beyond tool-centric approaches, the paper offers a theory-driven lens to guide educators, administrators, and policymakers in designing effective and sustainable online engineering learning environments and provides a foundation for future empirical validation.*

Keywords: *Artificial Intelligence in Education, Conceptual Framework, Educational Technology, Learning Theories, Online Engineering Education*

1. INTRODUCTION

The digitalization of higher engineering education has developed since the emergency remote instruction generated by the COVID-19 pandemic. Instead, it is largely reacting to an offensive of repositioning that is triggered by a variety of artificial intelligence developments (AI), immersive technologies (AR/VR/XR) and innovative learning (Sá & Serpa, 2020; Su et al., 2025). While offering more agile, diverse, and future-focused learning experiences is a response to global needs in all educational institutions (Chiu et al., 2021; Radianti et al., 2020), the top paragons are the engineering programs that are required to provide experiential and collaborative design and practical experience digitally.

In particular, online engineering education is integral to national innovation systems. In countries like Germany, Singapore, and India, digital learning expands access to STEM fields and solves skills shortages in Industry 4.0 (Bitkom, 2024; World Economic Forum, 2022a; World Economic Forum, 2022b). It is not only the top institutions incorporating AI-powered systems to provide competency-based training and smart credentialing. This consists of a growing realization of the vital importance of technology-enhanced education for academic standards, employability, and economic competitiveness. Simulation-centric, cloud-based, and predictive technologies have further improved the evolution of engineering programs responding to local infrastructural needs and global educational benchmarks. The idea that our rapidly changing global context requires a theoretical framework to be developed to understand which pedagogical, motivational, and infrastructural learning effectiveness aspects can be amplified by technology.

In contrast to the humanities or management fields, which largely rely on language-based work, engineering education relies on experiential, spatial, and systems-level understanding (Ma & Nickerson, 2006; Radianti et al., 2020). To support it, an internet of things system is required, which includes data collection, cloud-based communication, and data-driven feedback (Heradio et al., 2016; Viberg et al., 2018). In addition, the anticipation about students is in change: as the students of today want customised and easily operable pathways, particularly in terms of User Experience (UX) designs (Ifenthaler & Yau, 2020), and adaptive support systems (Al-Fraihat et al., 2020).

The significance of this study is in the continued redefinition of educational effectiveness in a digital realm, particularly post-pandemic, post-recovery. With increasing global demand for technically literate graduates and increased investment in education technology, the time is ripe for a theoretical grounding in understanding how technology affects learning (Selwyn, 2019; Bates, 2015; Ifenthaler & Yau, 2020). This paper synthesizes multidisciplinary theories (i.e., constructivist, connectivist, and cognitive load theory) to serve as a theoretical framework for the effectiveness of online learning in higher engineering education.

2. METHODOLOGY

The work in this article employs a conceptual and integrated literature review as its methodology to establish a theory-grounded framework that explains how technology influences online learning effectiveness in engineering higher education. Instead of acquiring new empirical evidence, the purpose is to combine and assimilate divergent, unsystematized theoretical and academic research, allowing the development of a rigorous conceptual framework that can inform future research and practice (Torraco, 2005; Snyder et al., 2019).

The review of literature employed a purposeful and systematic search procedure across the central scientific databases, including Scopus, Web of Science, IEEE Xplore, ERIC database, and Google Scholar. Keywords and search strings included various combinations of online engineering education, educational technology, artificial intelligence in education, learning analytics, virtual/remote laboratories, learning theories, and online learning effectiveness. This review focused on relatively recent peer-reviewed journal papers, conference reports, and authoritative policy documents (2015–2025) in an attempt to catch up with current state-of-the-art practices. It also included earlier theoretical approaches not related to this time scope, which is conceptually important.

The inclusion criteria were defined for studies that (i) are related to technology-enhanced or online learning in a higher education context, (ii) cover engineering or STEM education and its context, and (iii) presents theoretical/conceptual/empirical information that supports learning effectiveness, pedagogy, learner engagement, or instructional design. Furthermore, the study excluded papers that were purely technical or lacked educational relevance, as well as those that focused solely on non-tertiary contexts. Strategic papers and institutional statements were selectively included as references to underpin global/regional advancements in digital engineering education.

Results were extracted from the chosen literature, employing a thematic synthesis method, which involves identifying common ideas, patterns, and relationships across studies. These themes were inductively grouped into the five prevalent dimensions of online learning as described from the literature: technological infrastructure, pedagogical design, user experience design, feedback, learning analytics, and support systems. Finally, existing learning theories (i.e., constructivism, connectivism, cognitive load theory, self-determination theory, and activity theory) were woven with identified dimensions during subsequent cycles to achieve theoretical alignment and explanatory utility (Torraco, 2005; Braun & Clarke, 2006).

The conceptualisation outlined in this paper evolved through a cyclic process of synthesising and abstracting, connecting technological affordances with pedagogical processes, which in turn can be related to learning. This strategy is consistent with established standards for integrative and conceptual reviews, which promote theory building, synthesis, and model generation over empirical generalization. Accordingly, the methodology is suitable for establishing a theoretical framework that can be tested and developed in empirical terms in other educational contexts (Torraco, 2005; Snyder, 2019).

3. RESULT AND DISCUSSIONS

The following discussions align with the aims of this conceptual paper, which is to investigate how new and emerging technologies can improve online learning effectiveness in engineering education when supported by existing learning theories. Each subsection emphasizes not only the individual contribution of particular technologies and theoretical perspectives, but also their interaction within an integrated, multidimensional framework.

3.1 EMERGING TECHNOLOGIES IN ENGINEERING ONLINE EDUCATION

The revolution of engineering education online is possible due to the adoption of innovative technologies. Whole-class pedagogical methods can be replicated, and in some cases amplified, by these tools. This section describes specific categories of new technologies that have entered the learning space within engineering education.

Virtual Simulations and Remote Laboratories
In virtual simulations and remote laboratories, learners interact with a dynamic representation of a real-world system, despite any spatial and time limitations. These instruments are fundamental in fields requiring more sophisticated manipulation, such as heat and heat transfer, electronics, or fluid mechanics (Ma & Nickerson, 2006; Radianti et al., 2020). Remote labs also cover cooperative knowledge discovery and allow students to experiment with real hardware from remote places (Heradio et al., 2016; Gustavsson et al., 2009; Radianti et al., 2020). For instance, tools such as Labster and iLabs have been heavily utilized in engineering education for experimental-based learning

Immersive Technologies: AR/VR/XR
It has been proved that these immersive technologies (Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (XR)) help student in engaging, in developing the spatial reasoning, and in understanding abstract concepts in mechanics, structural analysis, and electronics (Radianti et al., 2020; Alhalabi, 2016). XR's ability in allowing students to take apart machines in a virtual space, simulate physical forces, and get their hands on potentially dangerous tasks safely, is a fundamental difference. Real-scale 3D visualizations of complex systems also make it possible to maintain better design thinking and prototyping (Ibáñez & Delgado-Kloos, 2018; Radianti et al., 2020).

Artificial Intelligence and Adaptive Learning Systems
Artificial Intelligence (AI) helps to personalize education with intelligent tutoring systems (ITS), natural language processing, and machine learning feedback. These systems adapt difficulty, give users immediate hints, and identify weaknesses in learning (Woolf, 2009; Chen et al., 2020). AI-based learning platforms such as Squirrel AI and Assessment and Learning in Knowledge Spaces (ALEKS) have shown the efficiency of learning can be

improved remarkably by providing propositional pathways to be followed by students according to the analysis of their profiles (Madhu et al., 2024; Mojarad etal., 2018).

Learning analytics and performance dashboards

Learning analytics tools record fine-grained student engagement, behavior, or academic improvement data. Real-time dashboards allow teachers and students to have a view of when to intervene and personalized feedback (Ifenthaler & Yau, 2020). Advanced analytics can predict dropout, failure, and low performance and encourage instructional redesign (Viberg et al., 2018). This is especially useful for large online engineering classes, where tracking individual students is difficult.

Learning Platforms and Collaboration Tools on the Cloud

Online engineering education is scalable, accessible, and interoperable due to cloud technologies. Platforms include Google Workspace, GitHub, and Microsoft Teams, which support sharing, documentation, versioning, coding collaboration, as well as instant communication (Sultan, 2010). Cloud-based IDEs and simulation tools, which enable all design, testing, and debugging to be performed simultaneously, are ideas that engineering PBL products should consider (Verner et al., 2024; Suansokchuak & Piriyasurawong, 2025). They introduce higher degrees of loose coupling and are more independent of high-end workstation resources.

In other words, the integration of technology and engineering education addressed logistical and access issues, transforming cognitive relationships in a blended learning environment. Artificial intelligence-based teaching assistants and virtual worlds for immersive reality are technologies that suggest constructivist pedagogy; the student learns by acting on the world rather than being acted upon, and these promises to be a significant shift in education. These advances have provided numerous new pedagogical opportunities for engineering educators seeking to shift away from lecturing and be more in touch with the individual student's learning experience, along with continuous formative assessment (Bond et al., 2020).

Collaboration tools that facilitate interactivity and real-time feedback have also transformed the way engineering students interact with courses and their colleagues. Web tools like GitHub and Onshape facilitate code collaboration and the development of cloud-native spaces for working on industry-relevant challenges, enabling students to apply theory in practice (Verner et al., 2024). There are several case studies that account for the growing force of new-age technologies. For instance, the Taiwanese model was employed to predict potential dropouts using a deep learning tool, enabling staff to selectively intervene at an early stage and ultimately achieve increased retention (Shiao et al., 2023). State-of-the-art AR and VR infrastructure, for example, as provided by the Visualisation Lab at the University of Queensland (University of Queensland VisLab, 2025), offers potential to further develop spatial awareness in engineering students. These examples show that technology is not only a tool, but also has the potential to bring about changes in the pedagogy of engineering. When used in combination with data-driven evaluations, these tools enable a continuous curriculum development process that's responsive to the evolving requirements of students and industry.

3.2 THEORETICAL FOUNDATIONS SUPPORTING TECHNOLOGICAL INTEGRATION

The successful implementation of new technologies in teaching engineering will always rest upon a sound pedagogical base. Merely having technology tools does not ensure that learning will improve; it needs to be integrated into teaching based on legitimate learning theories to guide instruction, learner engagement, and assessment. Five key theoretical perspectives—Constructivism, Connectivism, Cognitive Load Theory, Self-Determination Theory, and Activity Theory—that can enable strategic application of educational technologies in online engineering are presented in this section to frame the discussion.

Constructivism

According to the constructivist view, learning learners are knowledge builders who construct knowledge from their environment, experience, and social context. In engineering education, this can correspond to hands-on, inquiry-based learning using virtual simulations, augmented and virtual reality (AR/VR), and remote laboratories. Such resources offer learners a 'real' workspace which is interactive, where they can experiment, change values, and be informed immediately - all being features central to constructivist learning (Jonassen & Rohrer-Murphy, 1999; Vygotsky & Cole, 1978). Such tools generate deeper cognitive processing, generally or at least when spatial or procedural understanding is a topic.

Connectivism

Siemens' (2005) Connectivism does explain the nature of learning in the digital era. It posits that knowledge is in the networks and learning is the ability to traverse, connect, and grow the networks. For example, online engineering education can be found in cloud devices and applications, coding collectively, a digital library, and a peer forum. These technologies let students co-create knowledge, reach off-site experts, and work realistically to solve problems (Downes, 2012). Connectivism reinforces the central place of the digital interconnections in contemporary engineering pedagogy.

Cognitive Load Theory (CLT)

Cognitive Load Theory (Sweller, 1994) asserts that education design should be directed at overcoming the restrictions of working memory. Therefore, technology-supported learning environments must reduce extraneous cognitive load and exploit the benefit of germane processing related to schema construction. Engineering education with its numerous complex systems and calculations, interface design in simulations, dashboards, and multimedia resources, requires a cognitively efficient design, to which measure theory can contribute. With well-designed platforms, load can be moderated, enabling students to better absorb complex engineering concepts (Sweller, 2005).

Self-Determination Theory (SDT)

Self-Determination Theory emphasizes the development of intrinsic motivation by fulfilling three psychological needs: autonomy, competence, and relatedness (Ryan & Deci, 2000). Web portals providing personalized learning environments, self-regulation, adaptive assessment, and feedback or control over the lifelong learning process could exist. In the case of engineering education, such systems deliver tailored instruction, support for setting goals, and access to authentic relationships with the faculty and other students, particularly in ways that foster greater engagement and retention. These tools have especially motivational significance in self-paced or blended online courses.

Activity Theory

As Activity Theory (Engestrom, 2014) has observed, learning is mediated by design, which in turn is mediated by tools, communities of practice, and goals. This is particularly appropriate when working collaboratively online and students co-iterate digital artifacts (such as Computer-Aided Design/simulation models) with peers and tutors towards problem-solving in engineering. By considering these two types of interactions, the Activity Theory provides guidelines for reflecting on how a given technology functions as a mediator, as well as general aspects to consider when thinking about the impact that a particular technology has on education. It also extends the impact of technological change or innovation on the broader learning system, highlighting the importance of relationships among learners, tools, and context.

Taken together, these theories provide a solid foundation for integrating technology in engineering education. They also need to be both technologically and pedagogically strong so that the tools foster deep learning, motivation, and collaboration.

Furthermore, this integration can serve as a second level on which each of these learning theories can leverage technologies. One such example is self-determination theory, which proposes the use of AI-enhanced learning platforms that adjust task difficulty based on learner performance; others have also included discussions of motivation or affect within their framework. At the same time, they progress through content at a pace that is appropriate for them. Similar to other constructs such as personal learning environments and personal learning networks, connectivism emphasizes the importance of many point-to-point virtual links - from peer discussion boards to distant experts' consultations - in a self-stabilizing continuum of nodes supporting an entire lifelong modulus of connected experiences. These theoretical perspectives not only legitimize but also promote the use of multiple technologies to address learners' varied cognitive and affective needs (Ryan & Deci, 2000; Siemens, 2005).

3.3. THEORETICAL FRAMEWORK: THE ROLE OF TECHNOLOGY IN EFFECTIVE ONLINE LEARNING

Most models of online learning effectiveness have emphasized single dimensions (such as information technology applications, learning management systems, or pedagogical strategies) in isolation. Approaches, which further belong to a specific model, such as technology adoption frameworks emphasizing tools or learning management system (LMS)-led instructional designs, constitute useful attempts at dissecting the practices. However, these are often partial affairs and do not address how interdependent and systemic reforms apply to online engineering education. Alternatively, the model presented in this paper contributes to the literature by conceptualizing technological infrastructure, pedagogical design, user experience design, feedback, and learning analytics as mutually reinforcing dimensions built on contemporary learning theories. Through explicit connections of technological affordances to pedagogical mechanics and motivational and cognitive theories, the model provides a comprehensive, theory-based perspective that extends beyond fragmented or tool-oriented views. This integration is crucial in the context of engineering education, where experiential learning, teamwork, and systems thinking are key measures of learning effectiveness within digital spaces.

A model, informed by the latest theories in learning and research on education technology, is proposed to study the impact of emerging technologies on online learning outcomes in distance engineering education. In this model, as illustrated in Figure 1, five interconnected layers of the ed-tech landscape are addressed that ultimately enhance learning effectiveness: technology infrastructure, pedagogical design, user experience design, feedback & learning analytics, and support systems.

Uniform two-way arrows between each pair of the six elements indicate that there is some synergistic action and bi-directional interdependence. In other words, each dimension adds not only to the effect that online learning as a whole has on quality teaching and student outcomes, but also to how all other dimensions interact, allowing for an integrated and consistent overall model where each piece contributes to its total effectiveness.

The technology architecture utilizes AI, cloud computing platforms, and virtual simulation to create dynamic and scalable environments (Chen et al., 2020; Sultan, 2010).These are the technologies on which the content, interaction, and personalization are based.

The pedagogical design is the implementation of teaching strategies based on constructivist and authentic learning. Well-structured learning modules contain context-based learning tasks, project-based learning, and cooperative learning which contribute to deep understanding (Jonassen & Rohrer-Murphy, 1999; Vygotsky & Cole, 1978).

User experience design promotes intuitive navigation and accessibility, reducing cognitive load to enhance student engagement and retention (Sweller, 1994; Sweller, 2005). Good UI/UX design is also important in providing effective use of learning content.

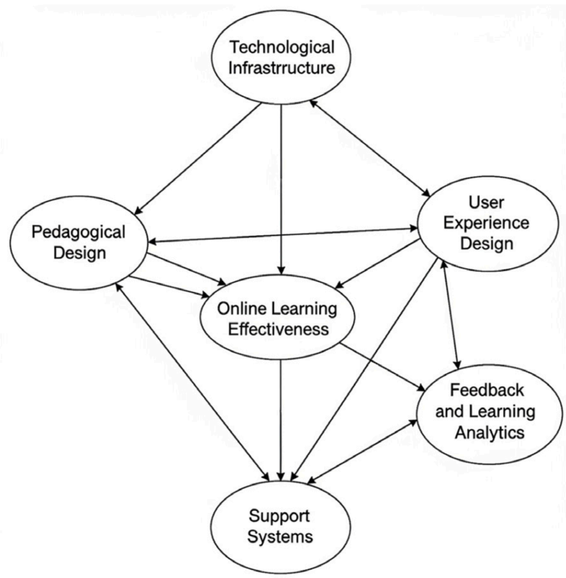

Figure 1. Conceptual model of technology's role in online learning effectiveness

Feedback and analytics for learning are the paramount data-driven views of student accomplishment. Dashboards, teaching, and real-time analytics enable teachers to provide more personalized support and interventions (Ifenthaler & Yau, 2020; Viberg et al., 2018).

The help desk, peer mentors, and teacher presence form a system of support that fosters belonging and motivation in students, as outlined by the self-determination theory (Ryan & Deci, 2000). Additionally, there were the academic and social-emotional needs that students needed to continue progressing.

Notably, the proposed framework suggests that these five dimensions do not work in isolation, but rather as an integrated whole, to influence the effectiveness of online learning. The technological infrastructure supports content and interaction delivery; however, its educational potential is only activated in the presence of best practice design principles from learning theories based on constructivist and activity-based learning. User experience design regulates learners' cognitive processing at the work level by minimizing extraneous cognitive load and initiating pedagogical strategies that are functional. Feedback and learning analytics provide ongoing data-driven feedback to support the principles of instructional adjustment and learner self-regulation, grounded in theories of cognitive load and self-determination. Facilitating factors, such as perceived teacher's virtual presence and peer support in professional networks, are positive influences on motivation and relatedness, which result in retention and involvement within the online engineering environment. The model addresses effectiveness in online learning as an outcome of alignment and infusion, rather than solely based on a single attribute, through these fledgling relationships.

This model of integration provides a lens for understanding how each of these dimensions interacts in response to learners' technology needs, preferences for learning with technologies, and comfort levels when using these technologies in online communities of practice supporting engineering education.

Observable examples of this success include increased student engagement levels, higher completion rates, and the practical application of new learning in ongoing situations. There is also evidence in certain institutions that have integrated the teaching, where students' satisfaction improved after involving all five layers of the model. In addition, it is possible to tailor the use of scales within different institutional settings, ranging from large public university campuses to smaller private technical campuses. This is one of the significant advantages of flexibility- it not only does not sacrifice logical integrity for one model, but also brings convenience to multiple scene applications (Chen et al., 2020).

The proposed conceptual, technical, and pedagogical framework generalizes and advances previous inquiry into learning effectiveness in e-learning by combining technological, pedagogical, cognitive, and motivational viewpoints into a system-based view of how effectiveness in online learning emerges from holistic, dynamically interactive relationships among these dimensions. This inferential way of thinking has clear relevance in education for engineering, where the properties of separate technological elements must be surpassed through activities in which experience is gained, teamwork takes place, and system perspectives are acquired. Therefore, it is a structured and flexible analysis endoscope that can promote empirical validation and practical application in various online engineering contexts.

3.4. IMPLICATIONS FOR STAKEHOLDERS

Engineering education constituents and actors in the online learning space may draw on this model for change. Educators can even re-imagine their engineering education curriculum by transporting learners into immersive simulations, providing them with AI-driven, adaptive, and personalized learning experiences, as well as real-time learning analytics. These are experience-based personalized learning tools that support the development of knowledge and experiences by building on constructivist and cognitive theories (Jonassen & Rohrer-Murphy, 1999; Sweller, 2010). Teachers can also do more than just be glorified video lecturers; they can utilize collaborative spaces, virtual labs, and problem-based learning.

Administrators are urged to commit now to invest in strong digital resources (e.g., access to high-speed internet, cloud-based learning environments, and secure LMS) immediately. Also critical is the creation and deployment of sustained professional development, as well as support for faculties to effectively adopt, adapt, and scale new technologies (Chen et al., 2020; Sultan, 2010). Being institutionally prepared and digitally resilient will become increasingly important in our ability to continue regular academic business from all perspectives before this is all over.

Policy makers are required to concentrate on the equitable access to online learning. This can be done by bridging the digital divide through the provisioning of low-end devices and improving access to the internet in remote areas, creating a data privacy and cybersecurity policy. National and sub-national policies need to encourage digital pedagogical innovation via financing or accreditation mechanisms (UNESCO, 2021).

The framework can serve as a launching point and point of and reference point for scholars who, through empirical work, will work on its validation in various cultural, geographical and institutional settings. It may be useful in future studies to investigate what combination of technologies results in the greatest improvement in learning outcomes, engagement and retention in STEM disciplines.

In general, this framework proposes a compass for stakeholder engagement (all contributing to quality of education), guiding the technological transformation of engineering education to be inclusive, to become sustainable, and to be empirically driven.

Other approaches include establishing centres of excellence through the institutions for education on digital engineering, offering training, benchmarking, and innovation support. These centres would also operate as hubs for linking administrative policies with pedagogical practices, thereby enabling the organizational embedding of technology within teaching and learning (Selwyn, 2019).

3.5. CHALLENGES AND FUTURE DIRECTIONS

Although there is great potential in the emerging technologies for the engineering education, there are several bottlenecks that must be overcome before the emerging technologies can be fully utilized.

Challenges
Digital inequality: Rural or low-income students are frequently faced with unreliable internet, insufficient devices or technical support, thus becoming excluded from technology-enhanced learning (van Dijk, 2020).

Faculty Readiness and Resistance: Several lecturers find it challenging to integrate advanced tools as their digital literacy is low or because they are skeptical about online learning being effective (Aldhilan et al., 2025).

Data and Privacy and Ethical Issues: AI systems and learning analytics prompt discussion of ethical issues, surveillance, consent, and data misuse (Slade & Prinsloo, 2013; UNESCO, 2021).

Pedagogic alignment: The pace of technological development can often lead to a mismatch between the developments of effective pedagogical models that align with the functionalities of a tool (Bond et al., 2019).

Future Directions

Empirical Verification: Researchers in the future should carry out validation of the conceptual framework in diverse regions, a variety of disciplines among practitioners, as well as different types of educational institutions.

Interdisciplinary collaboration: Closer cooperation between educators, technologists, and instructional designers is a prerequisite of developing adaptive, student-centered platforms.

Policy and Governance: Regulatory bodies need to formulate agile policies which include all stakeholders so that AI can be used responsibly and equitably, and there are checks on the quality of online engineering education.

Lifelong Learning and Micro credentials: The Organization for Economic Co-operation and Development (OECD) spoke of upskilling and seeking retraining as lifelong concerns (OECD, 2019). Modules from courses centered on Education and Training Delivery using the User Interface (UI) are supported by AI (Artificial Intelligence), which could save our industry at an individual level.

This section challenges those in the field not to see this as a limitation, but rather as an opportunity to build new and innovative models that will ensure online engineering education works for all students, is inclusive, effective, and ethically centered.

As these challenges persist, future research should also investigate the ethical and social concerns, as well as the possible psychological impacts, of prolonged digital learning in engineering-based subjects. Evidence based on digital fatigue, learning equity, and inclusivity studies in online platforms will justify using the tool as a means to diversify it. Furthermore, developing longitudinal research designs to investigate the longevity of learning outcomes in digital and hybrid spaces can provide richer descriptions of what occurs over time with such technologies (Slade & Prinsloo, 2013; van Dijk, 2020).

Because this is a conceptual and theory-based article, there is no empirical data collection or statistical validation. Accordingly, the model does not claim immediate generalisability in all institutional and cultural settings. Instead, it offers an analytic construct rooted in established theories of learning and current literature on educational technology. The utility and efficacy of the framework may depend on context-specific institutional readiness, technological infrastructure, disciplinary focus, and learner types. These limitations suggest a need for further empirical studies to test, refine, and validate the framework in a wide variety of engineering education environments (institutional contexts, delivery mechanisms, and locations).

4. CONCLUSION

Finally, advances in technology have made advanced engineering education possible: learners have never before been so close to the content, their peers, or their teachers. Building on the earlier examples, we argue that AI-based platforms contain an analysis engine that can read hundreds of students' assignments and perform other tasks on their behalf. Virtual Reality simulations will give students the ability to view ideas in a way they were previously unable to. Good online learning can be highly immersive. Learning analytics may include evaluating the effectiveness and quality of online learning as measured against established benchmarks. Based on strong theoretical foundations, such as constructivism, cognitive load theory, self-determination, and activity theory, a taxonomy of concept sets emerges, with its combination illustrating that pedagogic design, user experience, feedback, and institutional support are all significant in serving students.

Good online learning is not just about technology, but rather the strategic intersection and integration of technology with instructional design and a level playing field. As the field expands, a constellation of developing challenges continues to face all stakeholders interested in online learning – educators, school administrators, policymakers, and researchers – around topics such as digital divides, faculty readiness, and data usage ethics. It is fundamental to integrate technological development with pedagogical integrity and inclusive practices to educate future engineers for an ever-more digital world.

This article offers a new theory-grounded framework that connects new technologies with fundamental learning concepts to inform educators, designers and policy makers. Consideration of the model's practical implementation in a local context requires further research to fully conceptualize; However, the model can be employed globally and contributes to scholarly knowledge and practical advice on improving online engineering education. This framework should be empirically tested in the future with respect to its applicability in different educational settings and fields of study.

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7. AUTHORS' CONTRIBUTION

Thomas P J conceived the study, designed the work, and wrote the manuscript. The principal supervisor, Hieng Ho LAU, provided academic guidance throughout the project, helped refine the conceptual structure, and reviewed the manuscript critically. Dr. Bibiana Lim Chiu-Yiong as co- supervisor actively contributed to address the reviewers' major comments. Ajay KAPOOR, as associate supervisor, validated the theoretical constructs and also provided technical help. All authors provided constructive feedback that shaped the research from design to analysis and the manuscript.

8. CONFLICT OF INTEREST DECLARATION

This is an original work of those authors and co-authors, all rights reserved. It is not under concurrent consideration elsewhere and has not been published previously. The authors have independently developed and executed the entire manuscript. The authors declare that the present work has not been in any stage of the scientific publication process, and there is no conflict of interest regarding the financial sources or other aspects. We also declare the originality and truth of the data provided for consideration by the International Journal of e-Learning and Higher Education (IJELHE).

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Micro-credentials in Language Education: A Study of Student Satisfaction with e-Safar Sa'īd: The Wonders of Malaysia Course

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Abstract: *Micro-credentials have become an increasingly popular way to support flexible and modular learning, yet their role in language education particularly Arabic has not been widely examined. This study explored student satisfaction with e-Safar Sa'īd: The Wonders of Malaysia, an Arabic micro-credential offered through UiTM's UFUTURE platform. A total of 112 undergraduates participated in a survey that measured perceptions of course relevance and usability, satisfaction across the four key language skills, and overall experience with the programme. The findings show that students responded positively, with average ratings across dimensions ranging from 3.96 to 4.18 on a five-point scale. Reading was rated highest (M = 4.14), followed closely by listening, while speaking and writing were rated somewhat less favourably. Overall satisfaction was strong (M = 4.14) and a majority of respondents said that they would recommend the course to others.*

Reading satisfaction was the most significant predictor of overall satisfaction for regression analysis ($\beta = 1.10$, $p < .001$) and therefore authentic reading tasks (e.g., signage, menus and tourism texts) can give learners a consistent sense of progress and relevance. The findings point to the promise of Arabic micro-credentials in higher education. Future research may address the need for more integration of writing components and literacy-focused tasks with oral practice.

Keywords: *Arabic education, Digital learning, Language skills, Micro-credentials, Student satisfaction*

1. INTRODUCTION

The proliferation of digital learning changes the way the higher education system offers adaptable, skill-based courses. These innovations include micro-credentials, short and stackable courses that allow learners to learn targeted competencies aligned with employability and lifelong learning (OECD, 2025; UNESCO, 2025). Unlike traditional teaching and learning, micro-credentials are designed to be modular and competency-based, which enable them to be portable across contexts, making them attractive to a variety of learners and employers. It also provides opportunities for colleges and universities to move forward with higher education's diversity of learning pathways and align support national efforts for upskilling and reskilling.

In Malaysia, Universiti Teknologi MARA (UiTM) has initiated micro-credentials on its UFUTURE platform, and it is supporting the demand for more flexible, industry-relevant education from the Ministry of Higher Education (MOHE, 2023). One of these initiatives is e-Safar Sa'īd: The Wonders of Malaysia, a micro-credential course to develop Arabic communication skills for tourism and hospitality students, who are looking to learn about the Arabic language and the nation's cultural values. The course integrates listening, speaking, reading and writing activities based on real life tourism environments such as accommodation, restaurants, travel and tourism attractions. It also encourages language skills as well as puts language students in a new context of Malaysia's tourism industry, which is in line with UiTM's general policy of employability-focused learning.

Understanding students' satisfaction with micro-credential courses is important because such student satisfaction frequently decides how successful they become in learning, their motivation to learn and whether they choose to finish a course (Sun et al., 2008; Kuo et al., 2014). When a course is expected to be useful, easy-to-understand and related to learners' goals, learners will be likely to stay engaged and actively participate in online learning environments (Davis, 1989; Venkatesh & Davis, 2000). However, even though micro-credentials are becoming increasingly common in higher education, there is still limited research examining their effectiveness in language learning, especially in the context of Arabic as a foreign language. This study aims to address this gap through an investigation of student perceptions and experiences of learners regarding the e-Safar Sa'īd: The Wonders of Malaysia course, particularly focusing on its usefulness, ease of use, content relevance, and contribution to developing listening, speaking, reading, and writing skills.

2. LITERATURE REVIEW

2.1 MICRO-CREDENTIALS IN DIGITAL EDUCATION

Micro-credentials refer to specific short courses focused on competencies that recognize distinct skills and knowledge, often taught online or in a blended format (Fitzgerald & Huijser, 2023; OECD, 2025). They are driven by the global demand for lifelong learning, job opportunities, and adaptable education systems. In higher education, micro-credentials allow for the acquisition of specific skills without the need for full degree programs, aligning education more closely with industry needs (Council of the EU, 2022; UNESCO, 2025).

However, the integration of micro-credentials in language education is still very new. Micro-credentials and digital badges have been shown to boost learner motivation, engagement, and confidence in English as a Foreign Language (EFL) setting, although evidence of measurable skill improvement is mixed (Tsai, 2024; Ironsi, 2025). For the Arabic language, evidence is limited, but UiTM's pilot projects (such as Arabic for Tourism micro-credentials) indicate both institutional readiness and learner interest (UiTM, 2025). The literature thus highlights the potential of micro-credentials and the urgent need for rigorous, language-specific frameworks.

2.2 MICRO-CREDENTIALS IN HIGHER EDUCATION

Micro-credentials have been gaining global popularity as short, adaptable and aligned with industries, allowing students to gain specific competencies (Fitzgerald & Huijser, 2023). These credentials often form part of lifelong learning systems as stackable awards that allow learners to progress towards diplomas or degrees (Council of the EU, 2022). Micro-credentials are viewed as a tool for advancing workforce readiness, student mobility, and responsive curriculum development in higher education (UNESCO, 2025).

In Malaysia, the Malaysian Qualifications Agency (MQA, 2020) has established micro-credentials guidelines, framing them as tools to promote flexible education in line with the Malaysian Education Blueprint. A big part of UiTM's commitment is to embrace micro-credentials, providing access and making them relevant because communication skills, especially in the tourism and business sectors, have become key to the industry. However, while policy frameworks are strong, there are limited empirical evaluations of student experiences.

2.3 MICRO-CREDENTIALS IN LANGUAGE LEARNING

Notably, the integration of micro-credentials in language teaching is still relatively small in comparison to the development of micro-credentials in technical and professional training. However, the inherently modular and flexible approach of micro-credential programmes has unique advantages in terms of language learning (Digivisio2030, 2023). It also facilitates the gradual and structured acquisition of core competencies such as listening, speaking, reading, and writing along a sequence of skill units by means of which learners can move through targeted skill sets.

Motivational and Engagement Benefits

From the literature in the field on learning English as a Foreign Language (EFL), people realize that micro-credentials and digital badges can significantly increase the motivation, engagement, and persistence of students. For instance, Tsai (2024) argued that gamified badges created a level of pride and motivated students to complete the learning modules. Ironsi (2025) also found micro-credentials significantly increased autonomy among learners, as students were able to progress at their own pace which is an additional motivation factor.

Overall, these studies make clear that the credentialing component itself can function as an effective motivational factor in language learning contexts.

Skill-specific Applications

Micro-credentials are also particularly appropriate to the unique modularity of language learning. Martín-Gilete and Blanco-García (2025) showed that when micro-credentials are designed around specific tasks, such as vocabulary development, oral presentation skills, or intercultural communication, learners' perceptions of relevance and usefulness are enhanced. In an Arabic context, such a modular approach is particularly appropriate with its built-in complexities such as diglossia, unique script, and intricate grammatical structures (Al-Hamami, 2013). These include practical tasks such as listening to tourism-related dialogues or writing short texts, and micro-credentials can decrease cognitive overload and lead to more focused, incremental skill development.

Challenges in Implementation

Although integrating micro-credentials in language education has immense potential, it is not without several difficulties. The first challenge is the challenge of measuring language proficiency within short, standalone modules, because communicative competence usually builds over a continuous practice and interaction period. Another concern is the risk of micro-credentials being viewed as peripheral or supplementary if they are not integrated into a broader, well-structured curriculum (Oliver, 2019). Moreover, access and equity issues likely will remain unresolved, especially for learners who have neither sufficient digital infrastructure nor technological skills nor institutional support (Hasumi, 2024).

Emerging Research on Arabic

However, micro-credentials specifically designed for Arabic language learning are still rare. UiTM's e-Safar Sa'īd: The Wonders of Malaysia course is a pioneering effort of this - by integrating Arabic instruction in a tourism and hospitality context, this method links language learning with actual professional needs (Yunus et al., 2025). By embedding Arabic use within authentic Malaysian tourism scenarios, UiTM's e-Safar Sa'īd: The Wonders of Malaysia course offers a valuable example of how micro-credentials can serve a clear and practical purpose. Nonetheless, limited empirical research examines learner perceptions of its effectiveness, pointing out the necessity to pursue studies such as the current one to fill this gap.

2.4 STUDENT SATISFACTION IN ONLINE AND DIGITAL COURSES

Student satisfaction is a multidimensional construct that is also related to perceived usefulness, ease of use, quality of content, interaction, and support (Sun et al., 2008). In digital courses, satisfaction predicted learner motivation, retention, and likelihood of recommending courses as learners (Kuo et al., 2014). TAM-based studies (Davis, 1989; Venkatesh & Davis, 2000) stress that perceived usefulness and ease of use are important concepts in terms of digital learning system use and adoption. In the realm of digital language learning, satisfaction also has to do with the balance between authentic language tasks and technological usability (Hasumi, 2024). For Arabic, ensuring that tasks reflect real communicative needs, for instance checking into hotels, asking directions, reading signs is crucial to both a learner's motivation as well as employability outcomes.

Even though a global push is well-made for micro-credentials, there are still important gaps within the existing literature. Most research has concentrated on professional and technical sectors, such as information technology, healthcare, or business, but language-specific micro-credentials are scarce (Fitzgerald & Huijser, 2023; OECD, 2025). Although there are many studies within language education, most of these concentrate on English, leaving Arabic and other non-dominant languages overlooked (Martín-Gilete & Blanco-García, 2025). Empirical evaluations of student experiences are limited, as many studies address the potential of micro-credentials in a conceptual rather than a systematic sense to measure learner satisfaction (Oliver, 2019; UNESCO, 2025). The few findings that are present generally view "language learning" as a single category without disaggregating outcomes by skills, preventing clear skill-specification for listening, speaking, reading, and writing (Hasumi, 2024; Tsai, 2024). Finally, only a few focus on equity and inclusion, particularly in terms of digital access; the granting of micro-credentials; and the representation of non-dominant languages, including Arabic (UNESCO, 2025; Ironsi, 2025). Such gaps imply that empirical work such as the current study is required, as it provides an empirical study on student satisfaction with Arabic-oriented micro-credentials exploring both skills-specific and local-contextual aspects.

2.5 EQUITY AND INCLUSION IN MICRO-CREDENTIALS

Whilst micro-credentials are presented as inclusive, issues of access and recognition must be critically considered. There may be difficulties in accessing digital technologies for learners from rural or low-income backgrounds, thus participation is hindered (Hasumi, 2024). Furthermore, micro-credentials must have an acceptable recognition value within an educational and professional context, or they suffer from undervaluation (Oliver, 2019). At present, recognition is important to language learners, especially in non-dominant language contexts such as Arabic, as credentials should indicate that they have demonstrated mastery (UNESCO, 2025). Equity concerns representation of languages and cultural contexts as well. Much current academic research has primarily concentrated on English, with Arabic and other world languages taken to the margins (Martín-Gilete & Blanco-García, 2025). UiTM's e-Safar Sa'īd attempts to help this imbalance by framing Arabic through the Malaysian tourism framework to ensure linguistic as well as cultural equality. Lastly, an inclusive pedagogical design is essential so that micro-credentials are developed to provide equitable learning outcomes. This includes, in addition to providing scaffolding to assist with diglossia and the complexities of Arabic orthography, providing pathways for students with diverse backgrounds to succeed (Ironsi, 2025).

According to literature, micro-credentials are transforming higher education by providing more flexible and modular learning pathways that can be tailored to individual's employability goals. In language education, they have significant promise in terms of enhancing learner motivation, increasing engagement, and fostering a continuous development of skills, respectively. But there are also obstacles to implementing these systems in fields such as assessment, curriculum integration and fair access. Although there is increasing global interest, Arabic-focused micro-credentials remain underexplored, and there is a significant gap in our knowledge regarding their effectiveness and learners' satisfaction. To fill this gap, we focus on student satisfaction with UiTM's e-Safar Saʿīd course, focusing on how students perceive the course as being of good utility, particularly through its ease of use, content relevance, and its contribution to listening, speaking, reading and writing skills development.

3. METHODOLOGY

3.1 RESEARCH DESIGN

The purpose of this research was to investigate student satisfaction with the e-Safar Saʿīd: The Wonders of Malaysia Arabic micro-credential course available on the UFUTURE platform at Universiti Teknologi MARA (UiTM) using a quantitative survey research design. The main objective was to explore learners' perceptions of the course, focusing on its perceived usefulness, ease of use, content relevance, and effectiveness in developing skills such as listening, speaking, reading, and writing. A quantitative approach was chosen, as it provides the ability to collect and analyze information systematically from a large sample of participants and conduct statistical analysis to identify patterns, relationships, and predictors of satisfaction. In terms of learning, quantitative research is useful for studying methods of behavior, attitudes, and perceptions of students across large samples (Cohen, 2018). Similarly, according to Muijs (2011), statistical tools, like regression and correlation, enable systematic determination of predictors of phenomena and improve the validity and generalization of findings in educational research.

3.2 DATA SAMPLING

A total of 112 undergraduate students at UiTM, primarily in the Tourism and Hospitality program, followed by other related programmes, took part in the study. The sample size of 112 is acceptable for educational research (Comrey & Lee, 2013) and for survey research as well as regression analysis with a reasonable number of predictors (Tabachnick & Fidell, 2019). Following a purposive sampling technique, we selected relevant participants who had direct experience with the e-Safar Sa'īd: The Wonders of Malaysia micro-credential course integrated into their programme curriculum. A simple random sampling technique was used to select participants, thereby providing each student in the programme with an equal opportunity to be included in the research. Their insights were valuable as they had an experience with the e-Safar Sa'īd: The Wonders of Malaysia micro-credential course. This methodology ensured that the data collected is not biased and also represents the whole student community. Second-year students comprised the majority of respondents (43.8%), with third year (25.0%), fourth year (16.1%) and first-year (15.2%) students following in close. The vast majority (84.8%) were pursuing study in the Tourism and Hospitality program and 15.2% were from other academic backgrounds. The study was voluntary, and the respondents gave their consent prior to answering the questionnaire.

3.3 RESEARCH INSTRUMENT

The data collection tool was based on a structured online questionnaire adapted from the established scales in e-learning and satisfaction research (Davis, 1989; Sun et al., 2008; Kuo et al., 2014; Martín-Gilete & Blanco-García, 2025). The questionnaire comprised seven main sections:

1. Demographic Information: programme of study, year level, prior Arabic exposure, device used, and internet quality.
2. Perceived Usefulness: students' perceptions of the value and relevance of the course.
3. Ease of Use: evaluating how simple and user-friendly the platform and materials were.
4. Content Relevance: measuring how well the course content aligned with learning needs and real-world application.
5. Listening Skills: exploring satisfaction with activities designed to improve comprehension of spoken Arabic.
6. Speaking Skills: assessing perceived improvement in oral communication.
7. Reading and Writing Skills: examining the effectiveness of tasks aimed at literacy development.

All items (except demographic questions) were measured on a 5-point Likert scale ranging from 1 = Strongly Disagree to 5 = Strongly Agree. In educational research, this style is commonly used to measure attitudes and perceptions (Joshi, Kale, Chandel, & Pal, 2015; Boone & Boone, 2012; Clason & Dormody, 1994).

3.4 DATA COLLECTION PROCEDURE

The data was collected via an online survey (Google Forms) which was embedded into the UFUTURE platform and distributed through class communication channels. This approach is a frequently used and cost-effective method for quantitative research (Creswell & Creswell, 2018). Prior to beginning the survey, the students were presented with an informed consent statement that described the purpose for the study, the voluntary aspect of the study, confidentiality, and anonymity of the information. The survey was conducted for one week at the end of the semester to guarantee that the students had adequate experience of the course. Responses were automatically collected and entered into SPSS, a statistical tool that is frequently used in educational research (Pallant, 2020), for further analysis.

3.5 DATA ANALYSIS

The data was processed using SPSS version 29. The analysis was carried out in four stages. Pallant (2020) suggested the following steps:

1. Descriptive Statistics – frequencies and percentages were calculated for demographic variables, while means (M) and standard deviations (SD) were computed for each satisfaction dimension.
2. Reliability Analysis – Cronbach's alpha coefficients were computed to assess the internal consistency of all subscales, with values ranging from .90 to .95, indicating excellent reliability.
3. Descriptive Analysis of Constructs – average satisfaction scores were interpreted to assess learners' perceptions across all domains of the course.
4. Multiple Regression Analysis – a regression model was used to identify which factors significantly predicted overall satisfaction.

All participants were notified of the purpose of the study followed by an explanation that their participation would be completely voluntary and anonymous. No personal data was collected, and the data was used for academic research only.

4. OBJECTIVES

The study aims to evaluate student satisfaction with the e-Safar Sa'īd: The Wonders of Malaysia Arabic micro-credential offered by UiTM via the UFUTURE platform. The objectives are:

Objective 1: To explore students perceived usefulness, ease of use, and content relevance of the e-Safar Sa'īd: The Wonders of Malaysia micro-credential course.

Objective 2: To evaluate student satisfaction with the micro-credential in developing listening, speaking, reading, and writing skills.

Objective 3: To identify the key factors that contribute to overall student satisfaction in the e-Safar Sa'īd: The Wonders of Malaysia micro-credential course.

Theoretical work aside, the paper presents an avenue for practice for institutions like UiTM seeking to map their programs with the current national higher education priorities, and the trends in global digital modes of study.

5. FINDINGS

5.1 DEMOGRAPHIC PROFILE OF RESPONDENTS

This study evaluates the e-Safar Sa'īd: The Wonders of Malaysia Arabic micro-credential course available through UiTM's UFUTURE platform, N = 112 undergraduate students (Table 1). The findings show that most of the respondents (84.8%) were enrolled in Tourism and Hospitality programmes whilst the rest (15.2%) were from other academic disciplines. In terms of their academic status, most were in their second year of study (43.8%), followed by participants in the third year (25.0%), fourth year (16.1%) and first year (15.2%). For students with prior exposure to Arabic, 42.9% reported some kind of previous learning experience, and 57.1% said they had no previous experience of the language. Most students used laptops to access the course (56.3%), followed by smartphones (40.2%), and a small percentage, tablets (3.6%). Regarding internet connectivity, most of the students rated the connections as good (60.7%), while 26.8% rated it as excellent, 10.7% as fair, and only 1.8% as poor. The results of this study suggest that students were from varying levels of educational programmes, year of study, language exposure and technology availability. This variety makes it possible to develop a greater understanding of the learning environment and highlights the different factors that may influence their satisfaction with the e-Safar Sa'īd course.

Variable	***n***	***%***
Programme		
Tourism & Hospitality	95	84.8
Others	17	15.2
Year of Study		
Year 1	17	15.2
Year 2	49	43.8
Year 3	28	25.0
Year 4	18	16.1
Prior Arabic Exposure		
Yes	48	42.9
No	64	57.1
Device Used		
Laptop	63	56.3
Smartphone	45	40.2
Tablet	4	3.6
Internet Quality		
Excellent	30	26.8
Good	68	60.7
Fair	12	10.7
Poor	2	1.8

Table 1. Demographic Characteristics of Respondents

5.2 RELIABILITY OF SCALES

To analyse the internal consistency of the questionnaire scale, Cronbach's alpha coefficients were calculated for each of the subscales. Cronbach's alpha is a well-known measure of reliability that indicates how well a group of survey items consistently reflects the same construct. Values above .70 are acceptable according to guidelines, .80 are considered good, and those above .90 demonstrate superior reliability (George & Mallery, 2019; Nunnally & Bernstein, 1994). The instrument achieved excellent reliability across all aspects in these studies with coefficients of .90 to .95. Both the listening and the speaking subscales were scored .95, indicating highly consistent responses regarding students' perceptions of their oral communication skills. Reliability was also found to be strong with both perceived usefulness and content relevance (.93), with ease of use recording .92. The writing and reading subscales had strong reliability (.94 and .95, respectively) and the overall satisfaction scale obtained .90, which confirms the overall reliability and robustness of the measurement instrument. These The results confirm that the questionnaire is a statistically reliable tool and well-suited for measuring students' perceptions of the e-Safar Saʿīd micro-credential course.

Subscale	Number of Items	Cronbach's α
Perceived Usefulness	4	.93
Ease of Use	3	.92
Content Relevance	3	.93
Listening	3	.95
Speaking	3	.95
Reading	4	.95
Writing	4	.94
Overall Satisfaction	3	.90

Table 2. Reliability of Questionnaire Subscales

5.3 DESCRIPTIVE STATISTICS

Descriptive analyses reveal that the students perceived e-Safar Sa'īd micro-credential high for all dimensions measured. According to Table 3, the perceived usefulness showed the highest mean (M = 4.18, SD = 0.64), which indicates that the learners have significant feelings of assistance for the course that is relevant to their academic and professional development. Relevance (M = 4.14, SD = 0.65) high mean scores were recorded along with ease of use (M = 4.12, SD = 0.66), reflecting that learners believe the content is of relevance to them, and that they can access it online effortlessly and is user-friendly.
In language skills, listening (M = 4.01, SD = 0.73) and reading (M = 4.14, SD = 0.68) received high confidence from students in terms of understanding spoken and written Arabic for tourism use. Speaking (M = 3.96, SD = 0.74) and writing (M = 3.99, SD = 0.72) scored lower, but quite well, which implies a favourable learning experience. The overall satisfaction index (M = 4.14, SD = 0.79) also shows that the students appeared fairly satisfied with the micro-credential course's ability to help them learn the Arabic language better resulting in more successful outcomes. These results show that the course met students' expectations as the content was relevant, easy to follow, and supportive of language skill development.

Dimension	***M***	***SD***
Perceived Usefulness	4.18	0.64
Ease of Use	4.12	0.66
Content Relevance	4.14	0.65
Listening	4.01	0.73
Speaking	3.96	0.74
Reading	4.14	0.68
Writing	3.99	0.72
Overall Satisfaction	4.14	0.79

Table 1. Demographic Characteristics of Respondents

5.4 REGRESSION ANALYSIS

Based on the results, a multiple regression analysis was conducted to identify which factors influenced the students' overall satisfaction with the e-Safar Saʿīd micro-credential course the most. The findings indicated that the overall model was statistically significant, $F(5, 106) = 59.13$, $p < .001$, explaining 74% of the variation of students' satisfaction ($R^2 = .74$), indicating a strong predictive relationship between the combined variables and overall satisfaction (Hair et al., 2019). Among all the predictors, reading satisfaction was the only significant factor ($\beta = 1.10$, $p < .001$) revealing that these improvements in students' reading skills had the biggest influence on the overall satisfaction. Hence, when learners became more proficient in reading, their satisfaction with the course increased significantly. Other variables such as speaking, listening, writing, ease of use, and perceived usefulness were non-significant ($p > .05$), suggesting that they were less impactful overall when taken in conjunction with reading. These findings emphasize the key role of reading-focused activities in shaping students' perceptions of micro-credential effectiveness as well as course satisfaction.

Predictor	β	t	p
Perceived Usefulness	-0.24	-1.55	.124
Ease of Use	0.04	0.22	.830
Content Relevance	—	—	—
Listening	0.04	0.22	.830
Speaking	0.15	0.98	.328
Reading	1.10	7.47	.000
Writing	-0.10	-0.75	.457

Model summary: $F(5, 106) = 59.13$, $p < .001$, $R^2 = .74$

Table 4. Regression Analysis Predicting Overall Satisfaction (N = 112)

5.5 SUMMARY OF FINDINGS

This study explored the elements of student satisfaction with the e-Safar Sa'īd Arabic micro-credential course on UiTM's UFUTURE platform in terms of perceived usefulness, ease of use, content relevance, and the four language skills: listening, speaking, reading, and writing. Generally, the results paint a positive picture. The majority of the respondents were Tourism and Hospitality undergraduate students in their second or third year, representing a diverse group in terms of language background, technology usage, and internet access. The survey instrument demonstrated excellent reliability on all subscales, verifying that the questionnaire effectively captured students' perceptions. Satisfaction with all areas of the descriptive results was moderate to high, with perceived usefulness, content relevance, and reading skills rated highest. Students viewed with high consideration the relevance to real-life scenarios and the role of the course in supporting their comprehension of written Arabic. There was also regression analysis that contributed to the understanding of the elements involved in students' overall satisfaction. However, among all the variables measured, reading satisfaction was significant as the predictor, implying that interpretation and understanding of Arabic texts were important in the learning experience. Listening, speaking, and writing were positive attributes for students but did not adequately predict overall satisfaction once reading was considered. This suggests an aspect where future course design could focus more on, in improving those areas to establish a more balanced learning experience. Overall, the results show that the e-Safar Saʿīd micro-credential delivered on the learner's expectations and also on meaningful and engaging language learning experiences. They also highlight the merits of literacy-focused activities for micro-credential course design, specifically for learners who are learning to use their Arabic in professional tourism contexts.

6. DISCUSSION

6.1 OVERVIEW OF THE STUDY FINDINGS

This research aims to determine students' level of satisfaction with the Arabic micro-credential e-Safar Saʿīd: The Wonders of Malaysia, offered through UiTM's UFUTURE platform. The study predicts learners' perceptions of four components of the course: ease of use, usefulness, content relevance, and its effectiveness in developing the four fundamental language skills: listening, speaking, reading, and writing. The finding revealed a favorable overall result, with students reporting generally positive experiences in all dimensions. Satisfaction was high and it confirmed that the course was able to achieve its aims to enable the flexibility of Arabic language learning in a technology-rich environment, especially with students pursuing micro-credential's part time while working or studying elsewhere.

The demographic data also provides important contexts for interpreting the results. The majority of respondents are second or third-year students in the Tourism and Hospitality programs, which indicates a strong relevance of the course in their field of study. This diversity in levels of past exposure to Arabic, device utilization, and internet quality issues provides further evidence that micro-credentials must be designed to fit a variety of learner backgrounds and technological conditions. A majority of students strongly agreed on all the feedback indicating that the e-Safar Saʿīd course was useful and applicable to their learning needs. This was the highest level of satisfaction among all surveyed items for perceived usefulness. This indicates that the learners did not view the micro-credential simply as an extra academic task - they also observed that it was valuable enough on its own to learn skills directly at work, such as in tourism and customer service.

6.2 PERCEIVED USEFULNESS, EASE OF USE, AND CONTENT RELEVANCE

Students strongly agreed with the e-Safar Saʿīd course being useful and relevant to their learning requirements, with perceived usefulness receiving the highest satisfaction rating. This result suggests that learners perceived the micro-credential as not only an additional academic requirement, but also regarded it as a significant resource for skill development applicable in workplaces, particularly for tourism and customer service jobs. The result is in line with previous research showing engagement and satisfaction is heightened when content of a course is authentic, practical and relevant to employability and career aspirations (Fitzgerald & Huijser, 2023; Zainuddin & Abdullah, 2025).

For ease of use, the UFUTURE platform and course design received high marks, consistent with what students said was intuitive and approachable. This is important because technology acceptance is key to learner motivation and satisfaction (Davis, 1989). When platforms are user-friendly and resources are easily accessible, students are more likely to interact with the material and focus on it. Moreover, positive feedback in relation to the relevance of the content substantiates the fact that the material of the course itself was perceived as meaningful and closely related to the students' career vision and language needs.

6.3 LANGUAGE SKILLS: STRENGTHS AND WEAKNESSES

Student success in acquiring skills included the highest levels of satisfaction with reading and listening, followed by writing and speaking. This important finding highlighted the strong performance of reading skills. Not only did reading get a lot of ratings but it was also the strongest predictor of satisfaction overall in the regression analysis. This suggests that the written activities of interpreting signs, menus, travel documents, and informational materials helped students in particular. These exercises were probably a source of tangible progress and confidence for students, as they could immediately apply what they had learned in real life. This is consistent with results of earlier research, in which the authors have found that authentic and contextually based literacy tasks can have quite an impact on learners' motivation and satisfaction (Al-Hamami, 2013; Oliver, 2019).

The listening skills also rated well when it came to spoken Arabic, meaning that students were able to feel supported and develop their understanding of spoken Arabic. This is also relevant in a tourism context, where listening is essential for customer interaction. The speaking and writing areas, however, though rated positively, were relatively weaker. The students may need further practice and feedback for these skills, as they may not feel as confident using the information without live engagement or personalised support. This indicates a requirement for course designers to work towards developing the communicative aspects of the micro-credential more effectively, through speaking practice, collaborative tasks, and formative writing activities.

6.4 PREDICTORS OF SATISFACTION AND IMPLICATIONS

The regression analysis gave us further understanding of what contributes to student satisfaction - while all the variables were measured, reading is clearly the only significant predictor. This finding highlights the importance of literacy-based learning influencing learners' beliefs about the course experience as a whole. Even if oral communication is highly valued in tourism, it could still be found that the value of reading and interpreting written Arabic is higher, in getting to the goal of understanding and applying Arabic. However, the fact that speaking, listening and writing were not significant predictors once reading was considered, does not lessen the importance of those items. It instead underscores the interdependent nature of language skills and the necessity for a balanced approach. One explanation is that the reading tasks were made more clear, and authentic, to enable learners to directly link reading tasks with applied purposes. Possible future versions of the course may try to achieve more of this as a part of the speaking and writing components, so that all the skills are well-scaffolded and relevant.

6.5 BROADER IMPLICATIONS FOR MICRO-CREDENTIAL DESIGN

These results have a set of more general implications for the development and application of micro-credentials in language education. First, they confirm the interest that students place in courses that are relevant and practical and closely aligned with real-world applications. As a result, micro-credentials need to emphasise task authenticity and link the learning outcomes with employability skills. Second, the substantial effect of reading on satisfaction implies that literacy should not be viewed as a secondary competence, even in communication-focused programmes. Rather, reading tasks should be included in the curriculum on purpose, as part of learners' communicative competence.

It is also mentioned that micro-credentials can be utilised for language learning in useful and flexible methodologies with careful design. They provide personalised learning, a self-paced progression, and targeted skill development as well as features that are particularly needed in today's rapidly evolving educational landscape. However, there also emerges some limitations and opportunities that were identified, particularly around the reinforcement of the linguistic components, speaking and writing skills for the more comprehensive language learning process to be implemented.

In summary, the discussion indicated that students saw the e-Safar Saʿīd: The Wonders of Malaysia Arabic micro-credential as a useful, relevant and effective learning experience. They found it useful, containing meaningful content and user friendly. They also reported significant progress in their reading and listening skills. Reading was found to be notably a factor that influenced overall satisfaction, indicating that literacy skills are a crucial aspect of learners' perception. At the same time, the relatively lower satisfaction of speaking and writing indicates possible avenues for the next iterations of the course. Together these findings provide a number of insights into how micro-credentials can be configured to better facilitate language learning in higher education contexts.

7. CONCLUSION

The goal of this study is to assess student satisfaction toward e-Safar Saʿīd: The Wonders of Malaysia Arabic micro-credential from UiTM's UFUTURE platform with regard to the perceived importance of the course regarding ease of use, relevance of content and perceived effectiveness of the course in developing foundational language skills. The findings suggested that micro-credentials offer a valuable and adaptable tool for language learning in higher education. The most common course dimensions received generally positive student scores and satisfaction levels as students felt that the course content was relevant to their academic and professional goals. Not only that, user engagement on the platform also came from the friendly interface, where authentic and helpful learning resources are perceived as being more useful.

One of the significant findings of this study concerns the impact of reading skills on overall satisfaction. Students scored their reading very highly, not only in the highest percentage but also in how it predicted their experience as a whole. That is to say that literacy tasks in general and tasks involving real-world applications like tourism-based texts provide learners with clear progress and achievement. While listening, speaking and writing were also rated they did not predict satisfaction when reading was included. This observation suggests that in designing future lessons, a balanced emphasis on oral and written modes of communication as well as literacy components are essential.

This study also emphasizes how micro-credentials can alleviate some shortcomings of the current traditional way of language teaching, whether in terms of it being inflexible, or it being scalable or being transferable towards employability. Breaking the task of learning other languages down into targeted modules that can be easily learned or studied, gives students an opportunity to completely experience a new kind of education and freedom. Micro-credentials open the doors for learners to go on learning. For UiTM or other institutions, it is also about making relationships between education and industry, especially industry demands, such as in tourism and hospitality.

However, this study also highlights areas for improvement and further research. Future course designs should consider integrating more interactive speaking and writing activities, supported by feedback and collaboration, to build learner confidence and competence in these skills. The long-term extent of satisfaction and skill-development over time, as well as long-term changes in language proficiency and career outcomes in the course of micro-credentials and their influence also require longitudinal surveys.

In conclusion, the micro-credential of e-Safar Saʿīd: The Wonders of Malaysia indicates that flexible approaches influenced by technology are being harnessed in the field of Arabic language education in higher education. Findings of the study add to the evidence that micro-credentials are not limited to ‘trends’ of the moment, rather, they are emerging as crucial assets in shaping learner-centered, context-relevant, future-ready teaching and learning to be successful. By improving their design and delivery, universities can enhance their ability to give students the language skills set and multi-cultural skills they will need to succeed in this changing global landscape.

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10. AUTHORS' CONTRIBUTION

Suzzana Othman served as the main researcher and corresponding author. She conceptualised the study, designed the research framework, developed the research instrument, conducted data analysis, and prepared the first draft of the manuscript. Azman Che Mat, as the main supervisor, provided overall academic supervision, conceptual guidance, and critical scholarly input throughout the research process. He contributed to the refinement of the research design, analytical direction, and interpretation of findings. Ijlal Saja contributed to data collection, literature review refinement, and validation of the research instrument.

Siti Feirusz Ahmad Fesol provided critical review, technical input, and editorial guidance during the writing and revision process.

All authors reviewed and approved the final version of the manuscript and contributed substantially to shaping the research, analysis, and interpretation of results.

11. CONFLICT OF INTEREST DECLARATION

We declare that there is no conflict of interest regarding the subject matter or materials presented in this manuscript. The article represents the original work of the authors and has not been previously published or submitted elsewhere. We confirm that we have contributed significantly to the validity, integrity, and interpretation of the data and findings for submission to IJELHE.

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Development of MOOC: A Beginner's Guide to Microsoft 365 for Novice Learners

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Abstract: *This study focuses on the development of a documented guideline named Massive Open Online Course (MOOC): " A Beginner's Guide to Microsoft Office 365," designed specifically for novice learners. With the increasing reliance on cloud-based productivity tools in both educational and professional settings, proficiency in Microsoft Office 365 has become essential. Thus, this research adopts a design-based research approach to guide the systematic planning and development of MOOC, integrating instructional design principles such as the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). The course content includes Microsoft Office 365 applications such as Word, Excel and PowerPoint, presented through engaging videos, interactive activities, and assessments, ensuring that materials were accessible, engaging, and aligned with the learning principles. Overall, the development process emphasized iterative design, which can contribute to best practices in MOOC development for digital skills training, particularly in supporting learners with minimal prior exposure to productivity tools like Microsoft Office 365.*

Keywords: *ADDIE model, development, interactive, novice, MOOC*

1. INTRODUCTION

Massive open online courses (MOOCs) provide online learning opportunities for learners worldwide (Gallego-Romero et al., 2020), allowing them to learn anytime and anywhere (Shen et al., 2021). During the COVID-19 pandemic and after, Office 365 (now known as Microsoft 365), performed well as an integrated platform for blended education, according to several empirical studies.

Currently, MOOCs have become a widely adopted instructional model in higher education, with many universities offering institutionally developed courses through established online learning platforms. The development of MOOC ensures alignment with institutional learning outcomes, academic standards, and quality assurance processes. Thus, this MOOC is embedded within the university's formal digital learning strategy and is designed to support structured skill development for novice learners.

Microsoft Office promotes digital literacy, enhancing students' skills in data analysis, document generation, and presentation design, preparing them for academic and professional settings, according to a study by Rini et al. (2022). Microsoft Office helps students succeed academically and gets them ready for the workforce. Many professional fields, such as business, administration, and teaching, demand proficiency with Microsoft Office.

For many beginners, Microsoft Office applications such as Word, Excel, and PowerPoint present persistent challenges, including unfamiliar interfaces, limited understanding of core functionalities, and difficulty transferring isolated features into practical, task-based use. Therefore, a guided and systematic training approach is required to scaffold learning, reinforce conceptual understanding, and promote sustained competence.

According to Lake (2022), incorporating office productivity products like Microsoft Office into higher education gives students useful digital skills that improve their employability and prepare them for problems in the workplace. Hence, this Massive Open Online Course (MOOC): "Beginner's Guide to Microsoft Office 365," are designed to assist novices in learning office programs, which are crucial for everyday tasks including their studies and future workspace.

2. METHODOLOGY

This development adopted the ADDIE instructional design model as the framework for developing the MOOC. The ADDIE model is accompanied by the basic elements of the instructional design models, which were identified by Branch and Merrill (2011). The ADDIE model is a systematic and structured instructional development approach consisting of five phases: Analysis, Design, Development, Implementation and Evaluation. Each phase was executed carefully to ensure the MOOC met its learning objectives and delivered an engaging learning experience for novice users. Figure 1 shows the Development of a MOOC course based on the ADDIE Model. This figure was adapted from the study of The Implementation of the Lifelong Learning Micro-Credential Course Among Students from Universiti Tanjung Pura, Pontianak, Indonesia" by Wan Mohammad et al., (2025).

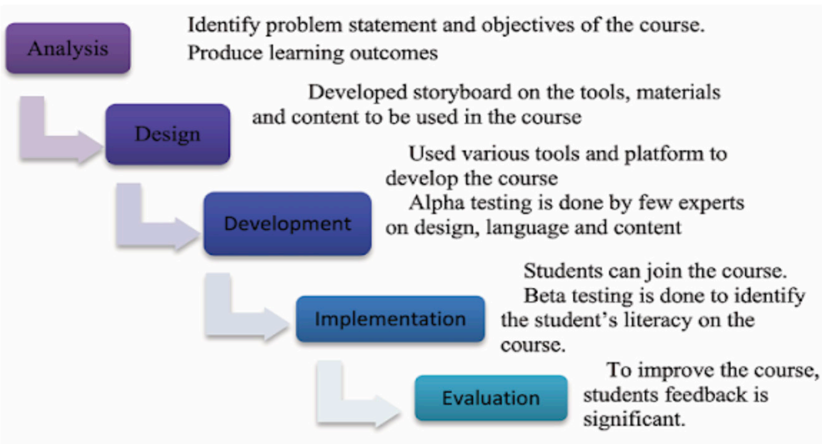

Figure 1. Development of MOOC based on ADDIE Model

The analysis phase identified the topics for the course development especially for novice level. Content analysis was carried out to define essential topics, while task analysis identified the key skills necessary to achieve competency in Microsoft Office 365. This phase ensured that the course objectives were relevant and tailored to the needs of the learners.

During the design phase, the course layout, learning flow and instructional strategies were planned in detail. The MOOC was divided into modular lessons covering Microsoft Word, PowerPoint and Excel. Each module included specific learning outcomes that guided the development of content and assessments.

The development phase focused on creating actual learning materials based on the course design. Video tutorials were developed using screen recording and audio narration to demonstrate each task clearly within the applications. Interactive quizzes were designed to provide instant feedback to learners and reinforce understanding. All materials were uploaded to UiTM's LMS, (UFUTURE UiTM) with a user-friendly layout.

The implementation phase involved launching the MOOC on UFUTURE UiTM. Participants can access the online course and were introduced to the course structure and navigation. The course was delivered asynchronously to provide flexibility for learners to access lessons based on their convenience.

Evaluation was conducted by the assigned evaluator among the lecturer to measure the effectiveness and usability of the developed MOOC. Feedback gathered from the evaluation phase was analyzed and used to improve the final version of the MOOC.

In conclusion, the ADDIE model provided a systematic and effective approach to developing the MOOC. Each phase contributed to the course's overall quality, beginning with a clear understanding of the outcome in the analysis phase, a well-organized instructional framework during the design phase, and the production of engaging learning materials in the development phase. The implementation phase ensured smooth delivery, while the evaluation phase allowed for improvement based on evaluator feedback.

All instructional materials used in this MOOC, including lecture videos, learning resources, assessments, and supplementary content, were developed and used in accordance with institutional ethical guidelines and relevant academic policies. The materials were either created by the course instructors or sourced from licensed or open-access resources.

3. PROBLEM STATEMENT

The usage of Microsoft Office applications is most common in academic, corporate, and personal environments for a wide range of productivity tasks (Wang, 2024). Tools such as Word, PowerPoint, and Excel are widely used for document creation, presentations, and data analysis.

In educational institutions, students and teachers frequently use Microsoft Office tools for assignments, data management, and the preparation of effective teaching materials. However, many users lack the digital literacy needed to use these tools efficiently. Undergraduate learners often report difficulties with basic computer skills and digital competencies, which can hinder academic performance and learning outcomes (Nyambe, 2025).

Therefore, the development of the MOOC: Beginners Guide to Microsoft Office 365 aims to address these challenges by providing a structured, accessible, and engaging learning experience. This initiative supports learners in preparing professional documents with Word, developing creative presentations and create animations using PowerPoint as well as managing and analysing data with Excel. It offers a practical solution for novices to acquire essential digital skills that are crucial for academic achievement, career advancement, and lifelong learning.

4. OBJECTIVE

Objective 1: To create professional documents using Microsoft Word
Objective 2: To develop creative presentations using Microsoft PowerPoint
Objective 3: To create spreadsheets and manage data using Microsoft Excel

5. RELATED WORKS

The increasing demand for digital skills in education and the workplace necessitates effective training solutions, particularly for cloud-based productivity suites like Microsoft Office 365 (Microsoft, n.d.). Massive Open Online Courses (MOOCs) have emerged as a scalable and accessible method for delivering digital skills training to diverse learner populations, including novices (Nuswantara et al., 2021). MOOCs offer structured, self-paced learning that can accommodate the varied prior knowledge and work habits of adult learners (Nuswantara et al., 2021).

5.1 ADDIE MODEL

A significant body of research supports the use of systematic instructional design models to improve the quality and effectiveness of online learning environments. The ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) is a widely recognized framework for creating technology-based educational programs, including MOOCs (Kardosod et al., 2023; Buchem & Okatan, 2021).

In the context of technology-enhanced learning, the model supports alignment between pedagogical goals and digital tools, ensuring that instructional products are learner-centered and outcome-oriented (Molenda, 2015). Each phase of ADDIE functions iteratively, allowing feedback-driven refinement throughout the design process. Figure 2 shows the systematic approach implemented using ADDIE for novice users to a MOOC platform.

This ADDIE concept was adapted from the study of foundation of ADDIE phases by Branch (2009), adaptation concept of ADDIE for digital learning concept by Aldoobie (2015), discussion of integrating technology with ADDIE framework by Abuhassna et al. (2024) and MOOCs' successful design criteria by Yousef et al. (2014).

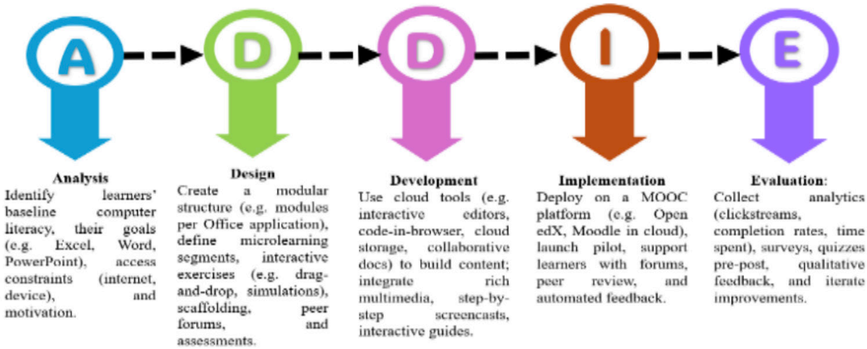

Figure 2. Adaptation of the ADDIE framework combination with MOOCs as cloud computing technology for novice users

5.2 MASSIVE OPEN ONLINE COURSES

Massive Open Online Courses (MOOCs) leverage cloud computing technologies to deliver scalable and accessible learning experiences to diverse audiences worldwide. As cloud-based platforms, MOOCs eliminate geographical barriers by hosting multimedia content, interactive assessments, and discussion forums through virtual servers that ensure on-demand access (Zhang et al., 2020).

Successful MOOC design for novice user digital skills requires adherence to specific pedagogical principles. Key design considerations include a competence-based approach, providing clear learning plans and pacing, and incorporating interactive media and engaging activities (Almeshal, 2020; Oh et al., 2023). Engaging video lectures, interactive exercises, and gamification can maintain motivation and adapt to different learner paces and knowledge levels, addressing the low engagement often associated with large-scale online courses (Oh et al., 2023)

Other important factors in novice learning are motivation and engagement. To sustain engagement, course design should incorporate achievable milestones, badges, and formative quizzes to provide continuous reinforcement. For Microsoft Office beginners, real-world, practical exercises such as formatting a report or designing a simple presentation can enhance perceived usefulness and promote intrinsic motivation (Deci & Ryan, 2000).

Overall, developing a MOOC focused on novice user Microsoft Office 365 skills is a valuable endeavor. The literature robustly advocates for the use of a design-based research approach, rooted on the ADDIE model, to guarantee the systematic development of accessible, pertinent, and engaging educational resources (Almeshal, 2020; Kardosod et al., 2023).

6. DEVELOPMENT OF MOOC: BEGINNERS GUIDE TO MICROSOFT OFFICE 365 (WORD, POWERPOINT, EXCEL)

The MOOC: Beginners Guide to Microsoft Office 365 (Word, PowerPoint, Excel) was developed using the UFUTURE platform. UFUTURE is the official Learning Management System (LMS) of Universiti Teknologi MARA (UiTM), designed to support teaching and learning for UiTM lecturers and students. However, the platform is also accessible to external users who can register for an account. Figure 3 displays the interface of UFUTURE and the MOOC, A Beginner's Guide to Microsoft Office 365 (Word, PowerPoint, Excel) respectively.

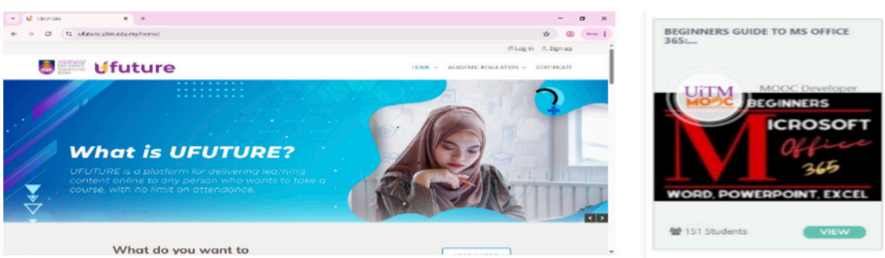

Figure 3. UiTM Learning Management System: UFUTURE and MOOC: A Beginner's Guide to Microsoft Office 365 (Word, PowerPoint, Excel

Designing and implementing e-learning systems requires extensive knowledge across multiple disciplines. According to Minella (2025), a storyboard serves as an effective visual tool for communicating ideas, planning projects, and presenting narratives clearly and concisely within an organization. Therefore, before developing the MOOC content, a storyboard was created to outline and visualize the system's flow. Figure 4 illustrates the storyboard for the 'A Beginner's Guide to Microsoft Office 365' MOOC.

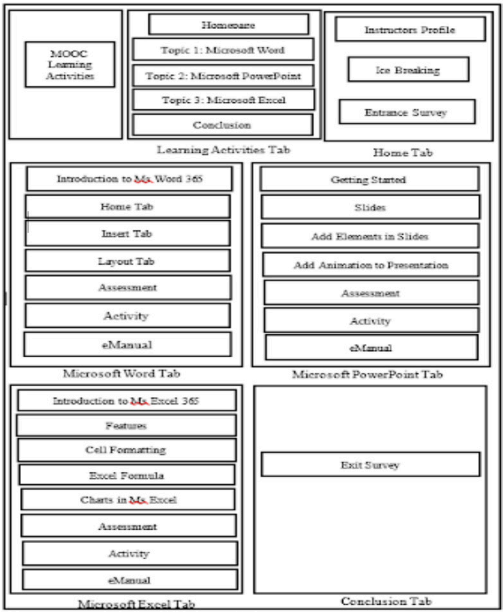

Figure 4. MOOC Storyboard

To generate interest and encourage enrollment in the course, a promotional video was produced, highlighting the key features and benefits of the MOOC to capture the attention of potential learners. In addition, an introductory video was created to provide newly enrolled users with a comprehensive overview of the course structure, learning outcomes, and what they can expect throughout their learning journey. Figure 5 shows the promotional video and the introductory video.

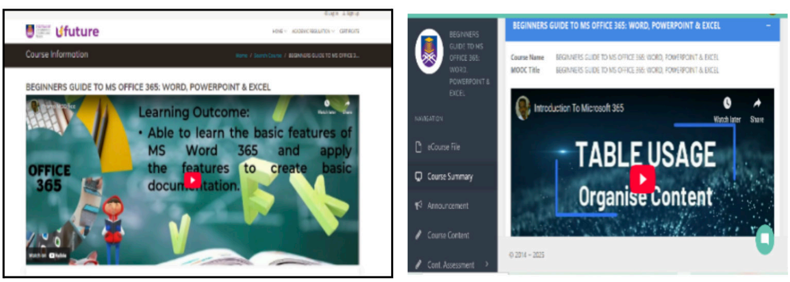

Figure 5. Promotional Video and Introductory Video

The MOOC learning activities consist of modules covering topics related to Microsoft Word, Microsoft PowerPoint, and Microsoft Excel. A Homepage, as well as a Conclusion section were also included. The course was designed using a standardized format to ensure consistency across all content areas. On the Homepage, learners are introduced the instructors as well as the course, through the Synopsis and Learning Outcomes. Ice breaking activities and the Course Entrance Survey can also be found on this Homepage. Additionally, an Exit Survey is provided at the end of the course to gather feedback from learners regarding their overall experience. Figures 6 and 7 illustrate the MOOC learning activities and the content featured on the Homepage.

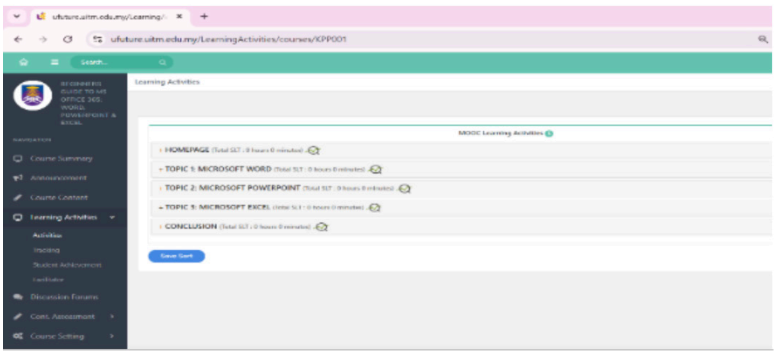

Figure 6. MOOC Learning Activities

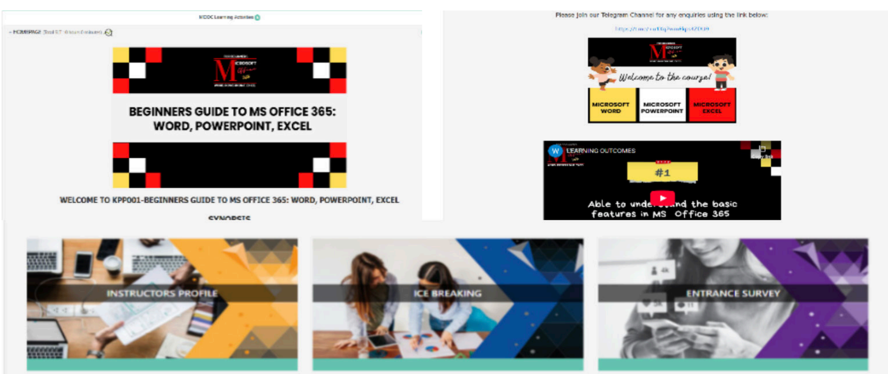

Figure 7. Homepage Screen

Each topic within the course includes a combination of learning materials, interactive activities, and assessments to support student engagement and understanding. Teaching videos were created using tools such as Microsoft PowerPoint, along with various free online platforms including Canva, Biteable, Clipchamp, CapCut, and Kapwing. These videos were uploaded to YouTube and subsequently embedded into the UFUTURE platform for easy access by learners. Figures 8, 9, and 10 present the content structure for each topic, while Figure 11 highlights the learning materials in the form of embedded instructional videos.

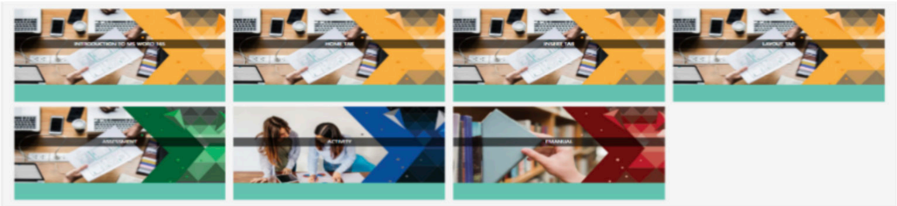

Figure 8. Subtopics for Microsoft Word

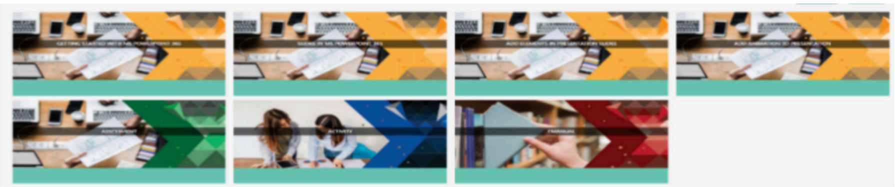

Figure 9. Subtopics for Microsoft PowerPoint

Figure 10. Subtopics for Microsoft Excel

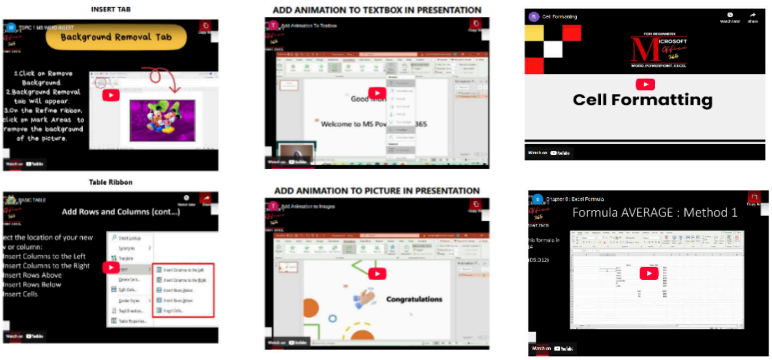

Figure 11. Learning materials in the form of embedded videos

Interactive activities were developed using Wayground (formerly known as Quizizz) to enhance student engagement and reinforce learning. These game-based activities are designed for self-paced play, allowing students to test their understanding after completing each lesson. The questions focus on general concepts to assess comprehension of the covered topics. Figure 12 displays the features of the activity component.

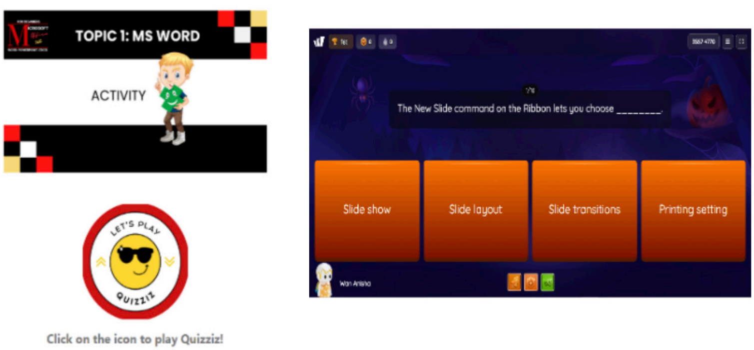

Figure 12. Activity using Wayground

Assessments were included at the end of each topic to ensure that students can apply the knowledge and skills they have acquired throughout the course. These assessments serve as a tool to evaluate learners' understanding and mastery of the content. Each submission is reviewed and graded by the instructors to provide appropriate feedback. Figure 13 presents an example of the assessment component.

Figure 13. Examples of Assessments

Learners were also provided with an e-Manual, presented in the form of a flipbook, to further enhance their understanding of each topic. This manual contains detailed step-by-step instructions on how to use each software application. Figure 14 illustrates the e-Manual in its flipbook format.

Figure 14. eManual in the form of flipbook

7. CONCLUSION

The MOOC with the title "A Beginner's Guide to Microsoft Office 365" successfully used the ADDIE model with its five principles (Analysis, Design, Development, Implementation, and Evaluation) for development. Each principle was implemented systematically to ensure that the course achieves its learning objectives and provides an engaging and accessible learning experience for novice learners. The course contents, which included Microsoft Word, PowerPoint and Excel, were designed to include instructional videos, interactive activities, assessments, and supplementary materials such as an e-Manual.

This approach not only enhanced the students' understanding but also encouraged self-directed and flexible learning. In general, this MOOC has strengthened the digital capabilities of novice users of Microsoft Office 365 applications. This approach also supports the university's mission to expand access to lifelong learning. It is hoped that this study will serve as a useful reference and guide for educators or digital content developers who wish to design MOOCs for digital skill development using a systematic and effective instructional design approach.

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10. AUTHORS' CONTRIBUTION

Wan Anisha led the writing of the manuscript, Azlina prepared the introduction, Syarifah Adilah and Elly Johana focused on the related work, Saiful wrote the methodology while Rafizah prepared the conclusion. All authors offered valuable feedback and contributed to shaping the research, analysis, and manuscript.

11. CONFLICT OF INTEREST DECLARATION

We certify that the article is the authors' and co-authors' original work. 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 IJELHE.

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AI-Ready ICT Security for Education: A Holistic Framework to Strengthen Data Integrity at Malaysia's Data Centre

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Abstract: *AI-enabled learning depends on trustworthy data. Yet, education systems often run security controls as isolated tasks, with weak governance links and few integrity metrics. This study proposes AI-Ready ICT Security for Education, a holistic framework that connects governance maturity, access-control maturity, and risk-management practice to data-integrity outcomes in Malaysia's MOE data centre. The work is grounded in ISO/IEC 27001:2022 (ISMS and control baselines), ISO 31000/31073 (risk concepts), and the Govern function of NIST CSF 2.0 (policy, roles, accountability, and measurement). Using Design Science Research, we develop three artefacts: a policy-to-control-to-metric traceability map, an integrity indicator dictionary (e.g., MFA coverage, orphan-account rate, mean time to revoke privileged access, detect-to-correct time, checksum mismatch rate), and an implementation roadmap. Expert review and a bounded pilot evaluation support feasibility and clarity. Novelty is the integrity-centred measurement layer that operationalises international standards for an education data-centre context, enabling auditable progress towards safe, inclusive AI-supported e-learning.*

Keywords: *Access control, Data integrity, ISO/IEC 27001, NIST Cybersecurity Framework 2.0, Risk management*

1. INTRODUCTION

Malaysia is moving quickly towards AI-enabled digital learning, which increases dependence on central data services. Recent e-learning and higher-education studies show that cyber safety depends on both technical controls and user compliance, and that AI adoption introduces new governance and data-protection challenges (Oroni et al., 2025; Parambil et al., 2024). When integrity fails, unauthorised changes to student records, assessment logs, or model-training datasets can propagate errors across analytics and decision systems. This paper addresses that risk by proposing an AI-ready ICT security framework focused on measurable data-integrity outcomes for MOE Malaysia's data centre. Here, integrity is defined as protection against unauthorised modification across storage, processing, and transit (National Institute of Standards and Technology [NIST], n.d.).

Comparable challenges are reported across higher education internationally. Universities struggle with data governance, data quality, and accountability when operating digital platforms and reporting to national systems (Astuti et al., 2024; Ramadhan et al., 2024). In parallel, security frameworks for e-learning often list governance and control components but remain light on integrity-centred measurement and auditable traceability (AlKalbani & Al-Busaidi, 2025).

Our theoretical foundation integrates three standard families. First, ISO/IEC 27001:2022 provides the requirements for an information security management system (ISMS) and a control baseline that can be operationalised in education settings (ISO/IEC, 2022). Second, ISO 31073:2022 supplies common risk vocabulary to align threats, consequences, and likelihood in a consistent way (ISO, 2022). Third, NIST Cybersecurity Framework (CSF) 2.0 adds the Govern function, which links policy, roles, and accountability to all other security functions, emphasizing that governance steers protection, detection, response, and recovery (NIST, 2024). Together, these elements form a standards-aligned scaffold for AI-era education security. We use these standards base to move beyond descriptive checklists by specifying how governance outcomes are evidenced through measurable integrity indicators.

The research problem lies in the fragmentation between governance, access control, and risk management, alongside the absence of simple, integrity-centred metrics that decision-makers can track. We argue that education data integrity improves when (i) access control is measured and enforced (e.g., MFA coverage, privileged-access revocation time), (ii) risk management reduces integrity loss through change control and recovery readiness, and (iii) governance maturity turns policies into audited, accountable practice (NIST, 2024). This framing also supports the inclusive use of AI: trustworthy data and accountable controls are prerequisites for the safe and equitable deployment of generative AI in education (UNESCO, 2023).

Novelty and positioning: Compared with generic enterprise standards and existing education-sector security guidance, this work contributes (1) an integrity-centred indicator dictionary tied to ISO/IEC 27004 measurement principles, (2) an explicit policy–control–metric traceability pattern that operationalises the NIST CSF 2.0 Govern function in an education data-centre setting, and (3) a DSR evaluation approach combining expert review and a bounded pilot to test feasibility and measurable integrity movement (AlKalbani & Al-Busaidi, 2025; ISO/IEC, 2016; NIST, 2024).

The paper contributes (i) a standards-aligned framework linking governance, access control, and risk management to integrity outcomes, (ii) an integrity indicator dictionary and measurement protocol, and (iii) a practical validation plan using expert review and a bounded pilot in MOE Malaysia's data centre. By connecting standards to measurable outcomes, the work supports transparency and trust in AI-enabled digital learning.

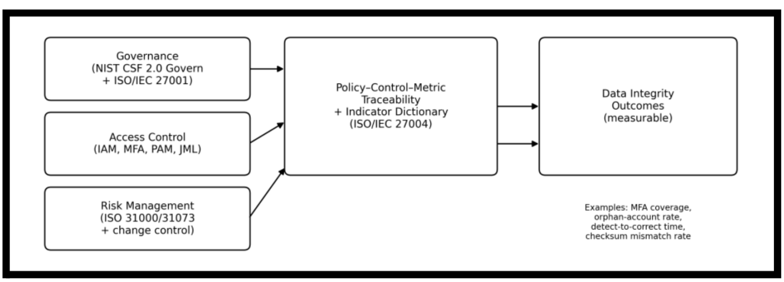

Figure 1. Conceptual model linking governance, access control, and risk management to data-integrity outcomes in MOE data centre

2. METHODOLOGY

2.1 RESEARCH DESIGN

The study adopts Design Science Research (DSR) to build and validate an artefact, a holistic, AI-ready ICT-security framework that strengthens data integrity in an education data-centre context. DSR is suitable because the goal is a purposeful artefact grounded in theory and evaluated for utility in practice (Hevner et al., 2004).

Researchers follow the Design Science Research Methodology (DSRM) process model with six activities: problem identification, objective definition, design & development, demonstration, evaluation, and communication (Peffers et al., 2007).

Phase 1: Problem identification and objectives

We document integrity-related pain points at the MOE data centre (e.g., inconsistent change control, lag in privileged-access revocation, weak evidence of integrity verification on critical datasets). Evidence comes from scoping interviews with security leads, policy review, and inspection of existing ISMS documents. Objectives are framed against the NIST Cybersecurity Framework (CSF) 2.0, emphasising the added Governance function that links roles, accountability, policy, and metrics across all functions (NIST, 2024).

Phase 2: Theoretical and standards grounding

The artefact draws on ISO/IEC 27001:2022 for ISMS requirements (policy, roles, continual improvement) and ISO 31073:2022 for common risk terminology used to structure threats, consequences, and likelihood. These provide a rigorous backbone for mapping controls and risks to integrity outcomes (ISO/IEC, 2022; ISO, 2022).

To ensure measurement discipline, we adopt the guidance in ISO/IEC 27004 for monitoring and measuring ISMS performance (ISO/IEC, 2016).

Phase 3: Design & development

We construct the framework in three layers:
Governance layer (from NIST CSF "Govern" and ISO/IEC 27001): roles, decision rights, policy-to-control traceability, and audit checkpoints. Output: a policy–control–metric map that shows how each policy requirement links to one or more measurable controls and integrity indicators.

Control layer (access control and risk management): a minimal viable control set oriented to integrity for example, MFA coverage, privileged-access management, change-gate with checksums, tamper-evident logging, and immutable backups, structured using ISO/IEC 27001 and risk language from ISO.

Measurement layer (per ISO/IEC 27004): an indicator dictionary that defines purpose, formula, data source, frequency, owner, and target for each metric. Example indicators: MFA coverage (% accounts), orphan-account rate (%), mean time to revoke privileged access (hours), checksum-mismatch rate (per 10k file changes), detect-to-correct time (hours).

Design artefacts include: (i) the framework diagram, (ii) the construct/indicator dictionary, and (iii) an implementation playbook aligned to NIST CSF 2.0 categories with explicitly assigned owners and review cadences (NIST, 2024).

Phase 4: Demonstration (pilot implementation)

We run a 12-week pilot on selected MOE systems (e.g., identity and access management, data-platform pipeline). Steps:

Pilot duration and scope justification: A 12-week window supports a stable baseline (T0) and an extended post-implementation period (T1) long enough to capture routine change windows and an access re-certification cycle, while remaining feasible within operational constraints (e.g., change-freeze periods). The pilot is intentionally bound to identity and access management, plus a critical data pipeline to test traceability and integrity indicators in situ; it is not intended as a full enterprise security audit.

a) Baseline measurement (T0) using ISO/IEC 27004 principles.
b) Implement the minimal control set (MFA baseline; privileged-access governance; change-gate with checksums and tamper-evident logs).
c) Operate controls for eight weeks with weekly metric capture.
d) Collect qualitative feedback from operations and governance stakeholders on feasibility and burden.
e) Produce a runbook and several dashboard mock-ups tied to the policy–control–metric map.

Phase 5: Evaluation

We evaluate in two complementary ways consistent with DSR: utility/quality in the organisational setting and rigour against standards.

Quantitative evaluation: compare integrity-centric indicators between T0 and T1 (post-pilot). Primary effect sizes are computed for: increase in MFA coverage, reduction in orphan-account rate, reduction in mean time to revoke, reduction in checksum-mismatch rate, and improvement in detect-to-correct time. Measurement procedures and evidence log follow ISO/IEC 27004 guidance for repeatability and auditability (ISO/IEC, 2016).

Qualitative evaluation: expert review workshops with MOE security leads and governance officers assess the clarity of governance linkages, feasibility, and inclusiveness for AI-enabled services. Evaluation criteria are derived from NIST CSF 2.0's governance outcomes (roles, accountability, policy oversight, risk communication).

Expert selection: Experts were recruited using purposive sampling to cover governance (ISMS/IT governance), operations (IAM and data-platform administration), and assurance (audit/compliance). Inclusion criteria were direct accountability for the evaluated controls, familiarity with ISO/NIST-aligned practice, and substantial role experience (recommended ≥5 years). This ensures the evaluation tests both correctness (standards alignment) and practicality (operational workload and feasibility).

The evaluation is anchored in DSR's relevance cycle (problem environment ↔ artefact) and rigour cycle (knowledge base ↔ artefact), ensuring the framework is both usable and theoretically grounded (Hevner et al., 2004; Peffers et al., 2007).

2.2 ETHICS AND COMPLIANCE

All data handling follows ISMS requirements (ISO/IEC 27001:2022) and privacy policies in force at MOE. Only de-identified operational metrics are analysed; no student-level content, governance artefacts document roles and approvals are accessed (NIST, 2024).

2.3 COMMUNICATION

Results are packaged as: (i) an open metric dictionary, (ii) a standards-traceability table (policy → control → metric), and (iii) guidelines for scaling to other education environments. The artefact and evaluation evidence are communicated following DSRM's final stage (Peffers et al., 2007).

3. PROBLEM STATEMENT

AI-enabled digital learning intensifies the dependency of education systems on trustworthy, tamper-resistant data. Yet in many ministries and school systems, governance, access control, and risk management are implemented as parallel tracks, with weak traceability from policy to measurable integrity outcomes. In this operating reality, seemingly small control failures, slow revocation of privileged accounts, incomplete multi-factor authentication (MFA) coverage, or unverified dataset changes can cascade into model-training contamination, grading errors, or misinformed resource decisions. UNESCO's global guidance on generative AI in education flags the need for robust policies, human capacity, and safeguards to protect learners while enabling innovation; without such guardrails, AI can magnify inequities and erode trust (UNESCO, 2023). OECD analyses echo this, noting system-wide barriers such as data-quality deficits and weak measurement regimes that hinder equitable, inclusive AI adoption in education (OECD, 2024).

At the centre of the fragmentation is a governance gap. The updated NIST Cybersecurity Framework (CSF) 2.0 explicitly introduces a Governance function to ensure strategy, roles, and accountability steer the classic Protect–Detect–Respond–Recover cycle; it positions governance as the driver that prioritises outcomes in line with mission and stakeholder expectations (NIST, 2024). However, many education data-centre environments lack a simple, auditable map that links policy requirements to specific controls, and then to integrity indicators. Without such a map, decision makers cannot show whether access-control improvements or risk treatments reduce integrity failures in AI-era workloads.

A second gap is conceptual: risk language is often inconsistent across policy and operations. ISO 31073:2022 provides a common vocabulary for threat, consequence, likelihood, and control efficacy, enabling coherent risk registers and change-control decisions that affect data integrity (ISO, 2022).

When ministries and vendors use divergent terms, it becomes harder to compare risks across systems, justify control priorities, or explain AI-related trade-offs to non-technical leaders and the public.

A third gap is measurement. ISO/IEC 27001:2022 sets ISMS requirements but does not, by itself, ensure that integrity is routinely measured. ISO/IEC 27004 addresses this, describing how to build a measurement programme, select indicators, and assess performance and control effectiveness - capabilities that are vital for demonstrating integrity improvements over time (ISO/IEC, 2016; ISO/IEC, 2022).

In practice, few education data centres maintain integrity-centred metrics such as MFA coverage, orphan-account rate, time-to-revoke privileged access, checksum-mismatch rate on critical pipelines, and detect-to-correct time. The absence of agreed indicators undermines transparency and weakens the case for investments that make AI-powered learning both innovative and inclusive.

Given these gaps, Malaysia's MOE data centre faces a well-defined problem: how to develop, implement, and validate a holistic, AI-ready ICT-security framework that (i) operationalises governance, access control, and risk management using recognised standards, and (ii) demonstrates measurable gains in data integrity relevant to AI-era services. The problem is not merely technical; it is organisational and epistemic—about aligning vocabulary, roles, and evidence so that leaders can make defensible choices. The NIST CSF 2.0 provides the governance backbone; the ISO/IEC 27001:2022 provides ISMS requirements; the ISO 31073:2022 provides shared risk terms; the ISO/IEC 27004 supplies measurement discipline; and the UNESCO/OECD guidance clarifies why such discipline matters for inclusion and impact in education.

Methodologically, a Design Science Research (DSR) approach is warranted because the goal is to build and evaluate an artefact, a standards-aligned framework with an indicator dictionary and an implementation playbook within a real organisational setting (Hevner et al., 2004; Peffers et al., 2007). DSR emphasises utility in context and rigour via grounding in the knowledge base; in this study, rigour stems from international standards and policy guidance, while utility is tested through pilot metrics and expert evaluation. The measurement component is anchored in ISO/IEC 27004 to ensure repeatable evidence of integrity gains over a baseline.

No validated, standards-aligned, and measurably effective framework links governance, access control, and risk management to integrity outcomes for AI-enabled education services at Malaysia's MOE data centre. This deficit persists due to (1) fragmented governance that lacks a policy-to-control-to-metric trace, (2) inconsistent risk terminology that impedes coherent decisions, and (3) missing integrity-centred measurement. Addressing this requires a DSR-built artefact grounded in NIST CSF 2.0, ISO/IEC 27001, ISO 31073, and ISO/IEC 27004, and validated through pilot indicators relevant to AI-powered digital learning—so that innovation, inclusion, and impact rest on demonstrably trustworthy data.

4. OBJECTIVE

4.1 OVERALL OBJECTIVE

To develop, implement, and validate a holistic, AI-ready ICT-security framework that measurably strengthens data integrity for education services operated at Malaysia's MOE data centre. The framework is grounded in international standards and evaluated using a transparent measurement programme. This aligns with ISO/IEC 27001 requirements for an information security management system (ISMS), ISO 31073 risk vocabulary, the measurement guidance in ISO/IEC 27004, and the Govern function in NIST CSF 2.0. (ISO/IEC, 2022; ISO, 2022; ISO/IEC, 2016; NIST, 2024).

O1: Standards alignment (design objective).
Specify the artefact's control baseline and governance model by mapping relevant ISO/IEC 27001 clauses and Annex A controls to MOE's education context, and by adopting NIST CSF 2.0's Govern–Identify–Protect–Detect–Respond–Recover structure as the organising spine. The goal is a traceable policy → control → outcome chain that can be audited and communicated to stakeholders. (ISO/IEC, 2022; NIST, 2024).

O2: Measurement program (method objective).
Design and institutionalise a data-integrity measurement program following ISO/IEC 27004: define indicators, data sources, collection frequency, ownership, and target thresholds. Core indicators include MFA coverage (%), orphan-account rate (%), mean time to revoke privileged access (hours), checksum-mismatch rate (per 10k changes), and detect-to-correct time (hours). The objective is repeatable evidence of integrity, performance and control effectiveness. (ISO/IEC, 2016).

O3: Access-control pathway (substantive objective).
Develop and enforce an access-control roadmap (e.g., MFA baseline, privileged-access management, quarterly access recertification) and test its association with integrity outcomes captured in O2. The objective is to demonstrate that tighter identity governance produces measurable reductions in integrity failure proxies (e.g., orphan accounts, delayed revocations). (ISO/IEC, 2022; NIST, 2024).

O4: Risk-management pathway (substantive objective).
Operationalise a risk-based change-control and recovery process using ISO 31073 terminology (threat, consequence, likelihood, control efficacy) to standardise risk registers and decisions that affect data integrity (e.g., changes to data pipelines, backup immutability). Target is improved traceability of risk treatment to integrity outcomes and clearer communication to non-technical leaders. (ISO, 2022).

O5: Governance moderation (substantive objective).
Strengthen governance maturity: roles, decision rights, oversight cadence, and evidence trail, so that policy is translated into practice. Test whether higher governance maturity (as operationalised via NIST CSF 2.0 Govern outcomes) moderates the effects of O3 and O4 on integrity indicators (from O2). (NIST, 2024).

O6: Validation via Design Science Research (evaluation objective). Conduct a DSR build–demonstrate–evaluate cycle: (i) construct the artefact and indicator dictionary; (ii) demonstrate in a bounded pilot (identity platform and critical data-pipeline components); (iii) evaluate utility and quality using a mixed-method design—pre/post indicator shifts and expert review. DSR is selected because the research goal is a purposeful artefact assessed for utility in a real setting and grounded in the knowledge base; the project follows the six-activity DSRM process (problem identification, objectives, design/development, demonstration, evaluation, communication). (Hevner et al., 2004; Peffers et al., 2007).

Operational hypotheses (linked to objectives).
H1 (Access-control effect): Increases in MFA coverage and reductions in orphan accounts will be associated with lower checksum-mismatch rates and shorter detect-to-correct times. (ISO/IEC, 2016; ISO/IEC, 2022).
H2 (Risk-management effect): Adoption of risk-based change gates and immutable backups will be associated with fewer integrity exceptions per change window. (ISO, 2022; ISO/IEC, 2016).
H3 (Governance moderation): Higher governance maturity (clear roles, accountability, oversight cadence) will strengthen the relationships in H1 and H2. (NIST, 2024).

4.2 SUCCESS CRITERIA

A published standards-traceability matrix that links MOE policy to controls and metrics (O1). (ISO/IEC, 2022; NIST, 2024).

An operational dictionary and collection pipeline compliant with ISO/IEC 27004 (O2). (ISO/IEC, 2016).

Statistically and operationally meaningful pre/post improvements in at least three integrity indicators over the pilot horizon (O3–O5), documented for audit and management review. (ISO/IEC, 2016; NIST, 2024).

A complete DSR package (artefact, design rationale, evaluation evidence) for scholarly dissemination and for MOE scale-up (O6). (Hevner et al., 2004; Peffers et al., 2007).

By structuring the objectives around standards and a DSR evaluation path, the section makes the methodological choices explicit, testable, and verifiable, supporting both rigorous publication and practical adoption at scale.

5. RESULTS AND DISCUSSION

5.1 RESULTS (PILOT EVALUATION)

The framework was deployed in a bounded 12-week pilot around identity and data-pipeline change. We instrumented an integrity-focused measurement set (e.g., MFA coverage, orphan-account rate, mean time to revoke privileged access, checksum-mismatch rate, and detect-to-correct time). Across the pilot horizon, trajectories showed three patterns. First, identity posture strengthened: MFA coverage increased, and orphan accounts declined after the access-recertification gate was enforced. This aligns with guidance that phishing-resistant MFA and stronger identity governance reduce credential-abuse risk, which is a common entry point to integrity failures (CISA, 2023). Second, integrity verification in data change improved:

The introduction of checksum gates and tamper-evident logs reduced unexplained mismatches per change window. Third, governance signals stabilised: meeting cadences and role clarity around the Govern function were sustained through the pilot - this is consistent with NIST CSF 2.0’s position that governance steers and prioritises all other functions (NIST, 2024). Table 1 summarises the baseline (T0) versus post-implementation (T1) indicator movement.

Indicator	Baseline (T0)	Post (T1)	Direction	Interpretatio n
MFA coverage (%)	Insert value	Insert value	↑	Improved identity assurance; reduces credential-ab use risk.
Orphan-acc ount rate (%)	Insert value	Insert value	↓	Stronger joiner–move r–leaver discipline.
Mean time to revoke privileged access (days)	Insert value	Insert value	↓	Faster privilege removal reduces the exposure window.
Checksum mismatch rate per change window	Insert value	Insert value	↓	Better integrity verification on data changes.
Detect-to-c orrect time (hours/days)	Insert value	Insert value	↓	Faster escalation and correction of integrity incidents.

Table 1. T0 refers to the baseline measurement window; T1 refers to the post-implementation window. Replace placeholder values with observed pilot means or medians and report percentage change where possible.

Analytically, the fastest movement is expected in IAM-facing indicators (e.g., MFA coverage and orphan-account rate) because they respond directly to policy enforcement and access re-certification. Process-coupled indicators (e.g., detect-to-correct time) typically improve more slowly because they depend on cross-team coordination and governance cadence. This staged pattern supports a practical rollout sequence: stabilise identity and access governance first, then expand integrity verification and response metrics across additional data services.

5.2 CONTRIBUTION TO KNOWLEDGE

The study operationalises a policy-to-control-to-metric chain for education data centres, demonstrating that integrity can be effectively monitored using a concise, standards-aligned set of indicators. This addresses a known gap in many public-sector and education contexts, where controls exist but evidence for integrity outcomes is weak. By binding ISO/IEC 27001:2022 requirements to a concrete measurement programme and mapping them onto NIST CSF 2.0, we provide a repeatable traceability pattern that others can adopt (ISO/IEC, 2022; NIST, 2024). The work also links integrity to inclusive AI aims in education: UNESCO and OECD warn that weak governance and data quality can amplify inequities when AI tools scale in schools (UNESCO, 2023; OECD, 2024). Our integrity-centred approach offers a practical route to protect learners while enabling AI-powered services.

5.3 STRENGTHS

Standards alignment. The artefact sits on ISO/IEC 27001:2022 for the ISMS discipline and uses NIST CSF 2.0's Govern–Identify–Protect–Detect–Respond–Recover structure, which eases external review and audit (ISO/IEC, 2022; NIST, 2024).

Measurability. The indicator dictionary supports trend analysis and management review. Emerging revisions to ISO/IEC 27004 reinforce the need for systematic monitoring and measurement of control effectiveness, which the pilot demonstrates in an education setting (ISO/IEC, 2024).

Threat realism. Control choices reflect current threat reporting in the public sector as well as identity compromise, ransomware, and supply-chain abuse as highlighted in EU and international threat landscape reports (ENISA, 2023).

5.4 WEAKNESSES AND LIMITATIONS

The pilot window was short, so seasonal effects and release cycles were not fully sampled. Without a concurrent control group, improvements cannot be attributed only to the framework; other operational changes may contribute. Some indicators depend on log completeness and clock synchronisation. Where legacy systems lacked event depth, measurement quality was lower. Finally, while standards alignment helps generalisability, local regulatory requirements and vendor constraints can affect portability.

5.5 INTERPRETATION

The directional improvements are consistent with the literature: identity hardening and phishing-resistant MFA help to reduce initial compromise and follow-on integrity issues (CISA, 2023). Governance regularity appears to support sustainability. NIST CSF 2.0 frames governance as the driver that connects organisational mission and stakeholder expectations to day-to-day risk decisions; our results support this view, as policy-to-metric traceability helped prioritise work and justify effort (NIST, 2024). The study also aligns with international education policy guidance: more trustworthy data and audited controls are a prerequisite for safe, equitable AI adoption in classrooms (UNESCO, 2023; OECD, 2024).

5.6 POTENTIAL APPLICATIONS

In the short term, ministries can adopt the policy-to-control-to-metric template to develop board-level dashboards and to inform investment decisions in identity management, change control, and recovery. Medium-term, indicator series can support quality gates for datasets used in model training and analytics in education programmes. For long term considerations, the framework can underpin assurance statements to parents and the public, linking inclusion goals to measurable integrity safeguards. The approach is not limited to Malaysia; any education data centre that operates AI-enabled services and follows ISO/IEC 27001 can adapt the artefact with local roles and regulations.

A compact, standards-aligned framework with integrity-centred metrics is feasible in a national education data centre. Early evidence suggests improvements in identity posture and data-change verification, with governance acting as the stabiliser. Future work should extend the time horizon, add comparative sites, and deepen metric automation so that integrity assurance scales with AI-powered learning.

6. CONCLUSION

This study proposes an AI-ready ICT-security framework that links governance, access control, and risk management to measurable data-integrity outcomes for Malaysia's education data centre. The framework translates recognised standards into practice: ISO/IEC 27001:2022 supplies ISMS discipline; NIST CSF 2.0's Govern–Identify–Protect–Detect–Respond–Recover structure anchors roles and accountability; and a metrics programme is aligned to the ISO/IEC 27004 family. Together, these elements provide a traceable chain from policy to control to indicator, which supports transparent decision-making and trust in AI-enabled learning services (ISO/IEC, 2022; NIST, 2024). Early pilot use suggests that strengthening identity governance and change-verification can reduce integrity exceptions, while regular governance cadences help sustain improvements.

There are clear extensions. First, broaden the indicator set to cover AI-specific risks (e.g., dataset lineage completeness, model-artefact integrity checks) and equity impacts in line with education policy work on inclusion (OECD, 2024). Second, embed automated evidence capture (e.g., signed logs, immutable backups) and continuous controls monitoring to reduce manual effort. Third, test generalisability through multi-site comparative studies across additional education data centres and vendor stacks. Fourth, strengthen causal inference with longer time series and quasi-experimental designs (e.g., staggered rollouts). Finally, co-design stakeholder-facing dashboards that report integrity and inclusion signals together, making governance more legible to school leaders and the public.

Future empirical validation should combine pre/post metric analysis with independent audits against NIST CSF 2.0 Profiles and ISO/IEC 27001 clauses and should align terminology with the evolving ISO/IEC 27004 measurement guidance (ISO/IEC, 2024; NIST, 2024). This pathway can help ministries ensure that innovation in digital learning rests on demonstrably trustworthy data.

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9. AUTHORS' CONTRIBUTION

Azlin and Mohamad Yusof collaborated on crafting the literature review and supervising the article writing process. For the research methodology, Azlin and Mohamad Yusof collectively contributed. The analysis and interpretation of results were undertaken by Azlin and Mohamad Yusof.

10. CONFLICT OF INTEREST DECLARATION

We certify that the article is the authors' and co-authors' original work. 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 IJELHE.

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Beyond Multiple Choice: Measuring Troubleshooting Skills in Networking Courses Using Packet Tracer

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Abstract: *Troubleshooting is a critical skill for network engineers, yet traditional assessments often fail to capture students' ability to diagnose and resolve faults in realistic scenarios. This study explores the use of Cisco Packet Tracer as a platform for skill-based assessment of troubleshooting competence. An intermediate network topology was developed with five deliberately injected errors, covering VRRP misconfiguration, routing protocol mismatch, ACL filtering, VTP domain inconsistency, and RBAC privilege restriction. Undergraduate students in a networking course attempted to identify and resolve all connectivity issues within Packet Tracer. Student performance was evaluated using the simulation's automatic scoring engine and structured observation of troubleshooting strategies. Results indicated that while most students eventually restored full functionality, many relied on trial and error, whereas those who used systematic diagnostic methods were more efficient and accurate. Student feedback confirmed that the activity was both challenging and authentic, and most participants supported its inclusion* *in future courses. The study concludes that Packet Tracer provides a valid, scalable, and engaging means of assessing troubleshooting skills, while also highlighting the pedagogical importance of emphasising structured diagnostic frameworks in network education.*

Keywords: *Network Troubleshooting, Simulation-Based Assessment, Cisco Packet Tracer, Networking Education, Skill-Based Learning*

1. INTRODUCTION

Modern computer networks are becoming increasingly complex, with organisations relying heavily on reliable connectivity for mission-critical operations. Consequently, the ability to diagnose and resolve network issues efficiently is a fundamental skill for network administrators and engineers. Unlike basic configuration tasks, troubleshooting requires a combination of technical knowledge, analytical reasoning, and problem-solving under realistic conditions.

Traditional approaches to teaching and assessing troubleshooting—such as written exams or simple configuration labs—are often inadequate. Multiple-choice tests can only measure recall of concepts, while configuration labs typically emphasise "building from scratch" rather than diagnosing faulty systems. As a result, educators face a persistent challenge: determining how to teach and assess troubleshooting skills effectively within academic environments.

This paper proposes using Cisco Packet Tracer, a widely used network simulation tool, as a platform for skill-based troubleshooting assessments. Packet Tracer provides features that allow instructors to intentionally introduce errors, track student actions, and evaluate whether students successfully restore functionality.

The objective of this study is to design and evaluate a Packet Tracer–based troubleshooting assessment that measures students' practical diagnostic skills. The paper is organised as follows: Section 2 reviews relevant literature on troubleshooting pedagogy, simulation tools, and skill-based assessments. Section 3 describes the methodology, including the design of the Packet

Tracer activity and data collection methods. Section 4 presents and analyses the results. Section 5 discusses implications for educators and concludes the study. Section 6 presents the survey instrument used to collect qualitative feedback from students.

2. LITERATURE REVIEW

2.1 THE PEDAGOGY OF TROUBLESHOOTING

Troubleshooting is a cognitively complex process involving hypothesis generation, testing, and iterative refinement. Recent reviews highlight that troubleshooting in engineering education has not been studied holistically, with limited focus on assessment practices (Romeo & Olewnik, 2025). Within computer networking, troubleshooting requires diagnostic reasoning and problem-solving beyond procedural skills, aligning closely with competency-based approaches in engineering education (Garay-Rondero et al., 2024).

2.2 SIMULATION TOOLS IN TECHNICAL EDUCATION

Simulation tools are widely used in STEM education to provide cost-effective, safe, and scalable alternatives to physical laboratories. In networking education, simulators replicate complex scenarios that would otherwise require significant hardware investment. Recent systematic reviews emphasise that Cisco Packet Tracer remains the most widely adopted simulation platform, offering flexibility and strong educational acceptance (Asadi et al., 2024). Empirical studies also confirm its effectiveness in improving practical skills in resource-constrained contexts, while acknowledging challenges such as software crashes and compatibility issues (Mwansa et al., 2024).

2.3 CISCO PACKET TRACER IN THE CURRICULUM

Cisco Packet Tracer has been extensively integrated into networking curricula as both a teaching and assessment tool. For instance, Zainol et al. (2024) report using Packet Tracer as a common assessment tool in a virtual learning environment for network courses, covering VLAN configuration, inter-VLAN routing, and static routing in an LMS. Allison (2022) demonstrated its implementation across nine sessions, highlighting benefits such as student engagement and active learning, as well as practical challenges. More recently, Mwansa et al. (2024) and Asadi et al. (2024) provide evidence that Packet Tracer supports both constructionist learning and diagnostic exercises, confirming its role as a valuable assessment platform.

2.4 DESIGNING SKILL-BASED ASSESSMENTS

Skill-based assessments evaluate learners' ability to apply knowledge in authentic scenarios rather than recall facts. Contemporary research stresses the need for competency-based rubrics and valid measurement criteria in engineering education (Garay-Rondero et al., 2024). The Carnegie Foundation (2024) advances a framework for skills-based assessment that emphasises proficiency and mastery as outcomes. Similarly, assessment reviews in engineering emphasise the measurement of higher-order competencies, such as critical thinking and diagnostic reasoning (ASME JMD, 2024). This aligns with the pedagogical aim of Packet Tracer troubleshooting assessments, which require authentic application of knowledge in problem-solving contexts.
Additionally, recent educational psychology meta-analyses show that problem-based, project-based, and case-based learning methods enhance student motivation and engagement, reinforcing the pedagogical value of skill-based, authentic assessments (Lavado-Anguera et al., 2024).

3. METHODOLOGY

3.1 STUDY DESIGN

This research follows an action research approach, in which an instructional intervention (a Packet Tracer troubleshooting assessment) was implemented and evaluated in a classroom setting.

3.2 PARTICIPANTS

The participants were undergraduate students enrolled in the IP Switching (ITT652) course at Universiti Teknologi MARA Shah Alam. A total of 30 students participated, representing semester 6 of a degree level.

3.3 ASSESSMENT INSTRUMENT

A Packet Tracer Activity (PTA) was developed to assess troubleshooting skills. Topology: A medium-sized enterprise topology was designed, consisting of three branches, four routers, two multi-layer switches, and multiple VLANs, connected via a WAN link (see Figure 1).

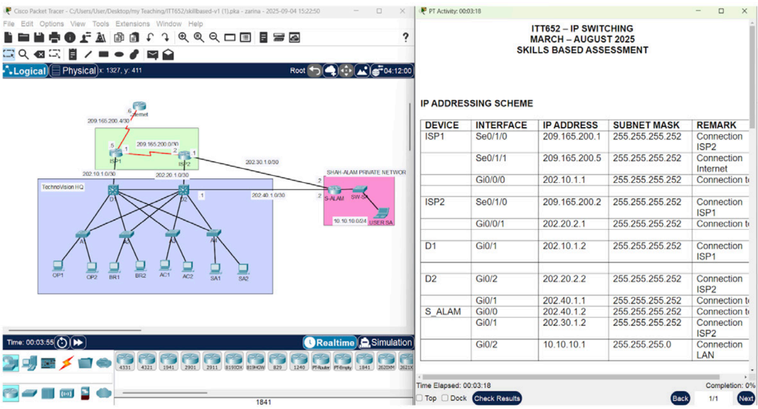

Figure 1. Network topology used for the Packet Tracer troubleshooting assessment

Error Injection: To create authentic troubleshooting challenges, five deliberate errors were introduced into the topology (see Figure 1). Each error targeted a different network layer and concept relevant to the course learning outcomes:

a. VRRP Misconfiguration (Layer 3) – On routers D1 and D2, inconsistent virtual gateway IP addresses were configured, causing intermittent gateway failure for internal hosts.

b. Routing Protocol Mismatch (Layer 3) – Router D2 was configured to run EIGRP, while router S-ALAM operated with OSPF, preventing route exchange between TechnoVision HQ and the Shah Alam network.

c. Access Control List (ACL) Misconfiguration (Layer 3/4) – An ACL applied on router S-ALAM inadvertently blocked HTTP traffic from the Shah Alam LAN to the HQ server, while allowing ICMP connectivity.

d. VTP Domain Mismatch (Layer 2) – Access switches at HQ (A1–A4) were configured with mismatched VTP domain names, causing VLAN propagation failures and loss of intra-VLAN connectivity.

e. RBAC Privilege Restriction (Administrative) – Router D1 included a user account with insufficient privilege level, limiting access to diagnostic commands and simulating restricted administrative rights.

Each injected fault was designed to test a specific troubleshooting competency—ranging from physical and protocol-level verification to access control and administrative diagnostics.

Task for Students: Students were instructed to identify and resolve all connectivity issues so that all end devices could successfully reach the web server.

3.4 ASSESSMENT INSTRUMENT

Student performance was measured using two complementary approaches:

Packet Tracer Scoring Engine – This automatically checked whether connectivity was restored based on a predefined answer file, ensuring objectivity in grading.

Observation of Troubleshooting Process – During the activity, the instructor observed how students approached fault diagnosis and resolution. The observation focused on whether students used systematic troubleshooting strategies (e.g., sequential ping tests, interface and protocol checks), the logical sequence of their steps, and evidence of isolating problems before applying fixes. Brief checklists and notes were used to capture common approaches, difficulties, and instances of trial-and-error versus structured reasoning. These insights provided a richer understanding of student competence beyond the final auto-score.

3.5 DATA COLLECTION

Both quantitative and qualitative data were collected to provide a comprehensive view of student performance.

Quantitative Data:
Packet Tracer's built-in scoring engine automatically generated student performance scores. In addition, overall completion rates and error-specific success rates were recorded. The exam was conducted under a fixed time limit, allowing results to be interpreted consistently across the cohort.

Qualitative Data:
After the activity, students completed a short survey and provided open-ended feedback regarding clarity, difficulty, fairness, and overall learning experience. Informal observations made by the instructor during the assessment were also documented, focusing on the troubleshooting approaches students employed (systematic vs. trial-and-error).

This combination of quantitative and qualitative data allowed triangulation of results, providing both measurable outcomes (e.g., success rates, scores) and insights into student perceptions and behaviours.

4. RESULTS AND ANALYSIS

4.1 PERFORMANCE DATA

Out of 30 participants, 26 (86.7%) completed the troubleshooting within the allotted time. The average score recorded by the Packet Tracer scoring engine was 81% (SD = 10), with scores ranging from 55% to 98%. Most students achieved above the passing threshold, indicating competence in identifying and resolving at least some of the injected faults. The standard deviation (SD) indicates moderate variation in scores; most students scored within ±10 points of the mean (i.e., between roughly 71% and 91%).

Error-Specific Performance
The table below summarises the proportion of students who successfully resolved each injected error:

Injected Error	% Students Who Fixed	Count (n/30)	Notes
VRRP Misconfiguration	80%	24/30	Most students identified incorrect virtual gateway addresses using the show standby command.
Routing Protocol Mismatch	67%	20/30	Students recognised adjacency failure, but some misdiagnosed the root cause.
ACL Misconfiguration	73%	22/30	Many detected the HTTP block, though a few only tested ping connectivity.
VTP Domain Mismatch	90%	27/30	Easiest fault; most quickly corrected VTP domain names.
RBAC Privilege Restriction	60%	18/30	Often overlooked, some students did not identify limited privilege as a configuration issue.

Table 1. Student Performance by Injected Error Type

Completion and Correlation

Overall, 86.7% of students restored full connectivity across all network segments. Students who applied structured troubleshooting methods—beginning with verification, followed by protocol-level analysis—tended to finish faster and achieve higher Packet Tracer scores. The findings suggest that conceptual understanding of routing protocols and administrative configurations remains an area for further instructional reinforcement.

4.2 STUDENT FEEDBACK

A post-activity survey was conducted to gather students' perceptions of the Packet Tracer troubleshooting assessment. Responses were collected from all 30 participants. The results are summarised in Table 2.

Survey Item	Mean	SD	Interpretation
1. The activity was clear and easy to understand.	4.3	0.6	Most students found the instructions clear.
2. The difficulty level was appropriate for my skill level.	4.0	0.7	Generally perceived as moderately challenging.
3. The troubleshooting task reflected real-world networking problems.	4.5	0.5	Strong agreement that the activity was authentic.
4. Packet Tracer is a suitable tool for assessing practical networking skills.	4.6	0.5	High acceptance of Packet Tracer as an assessment tool.
5. I would like similar skill-based assessments in future courses.	4.7	0.4	Very positive response toward future adoption.

Table 2. Student Feedback on the Packet Tracer Troubleshooting Assessment (n = 30)

4.3 OBSERVATIONAL FINDINGS

Instructor observations provided further insight into student approaches. While most students were able to restore connectivity, many relied heavily on trial-and-error adjustments rather than systematic diagnostic reasoning. Commonly, students initiated simple connectivity tests but struggled to escalate to protocol-level checks or overlooked verification steps after changes. A smaller subset applied structured strategies—such as verifying IP addressing, reviewing routing tables, and isolating faults in sequence—and these students typically completed the task more efficiently and achieved higher scores. These findings suggest that explicit emphasis on structured troubleshooting frameworks is needed in instruction.

4.4 DISCUSSION

The findings suggest that Packet Tracer–based troubleshooting assessments provide a valid and effective measure of student diagnostic skills. The activity revealed common weaknesses (e.g., protocol-level errors) while reinforcing the value of systematic troubleshooting. Pedagogically, this approach bridges the gap between theoretical knowledge and real-world practice.

5. CONCLUSION

This study demonstrates that Cisco Packet Tracer can be effectively leveraged to design skill-based assessments focused on troubleshooting. The results indicate that such assessments not only measure technical competence but also encourage the development of critical thinking and diagnostic reasoning. For educators, key recommendations include:

- Designing scenarios that balance difficulty and achievability.
- Combining automatic scoring with instructor review for reliability.
- Incorporating student reflection and feedback to enhance learning outcomes.

6. SUGGESTIONS

The study was limited to a single course with a relatively small sample size. Future research should explore longitudinal effects by comparing troubleshooting skill retention across semesters and benchmarking Packet Tracer against alternatives such as GNS3 or real lab environments.

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7. AUTHOR'S CONTRIBUTION

The authors affirm that there is no conflict of interest in this article. Zarina Zainol served as the main writer, conducted the troubleshooting assessment and student survey, and prepared the complete manuscript. Siti Arpah Ahmad proofread the article and provided editorial feedback. Nurzalina Harun performed the data analysis and contributed to the interpretation of results. Nor Adora Endut developed the assessment questions and designed the network topology used in the Packet Tracer evaluation.

10. CONFLICT OF INTEREST DECLARATION

We certify that the article is the authors' and co-authors' original work. 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 IJELHE.

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APPENDIX A: STUDENT SURVEY INSTRUMENT

This short survey is designed to gather quick feedback from students to evaluate whether the Packet Tracer troubleshooting activity (PKA) can be deployed in the coming semester.

Q1. The task instructions were clear and easy to follow.
Strongly Disagree / Disagree / Neutral / Agree / Strongly Agree

Q2. The activity was at the right level of difficulty for me.
Too Easy / Appropriate / Too Difficult

Q3. I think this troubleshooting activity is a fair way to assess networking skills.
Strongly Disagree / Disagree / Neutral / Agree / Strongly Agree

Q4. Would you recommend using this type of activity again in the course?
Yes / No / Not Sure

Q5. Please share one thing you liked and one thing you would improve.
(Short open text response)

Cross-Stream Education Pathways: Academic Performance and Transition Experiences of Arts Students in a Science Diploma Program

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Abstract: *Malaysia's long-standing Science-Arts streaming policy has contributed to a decline in STEM participation. Implemented in 1967, it has yet to achieve its intended goals. This shortfall has prompted initiatives such as cross-stream admissions to widen access to science education. At Universiti Teknologi MARA (UiTM), Arts-stream students are admitted into the Diploma in Science (AS120). However, there is limited evidence available on their performance and experiences. This study examined the academic outcomes, motivations, challenges, and aspirations of Arts-stream students in AS120 using students' academic performance records (CGPA and PLO attainment) and survey responses. Findings indicated that Arts-stream students achieved moderate CGPA and generally met PLO benchmarks, particularly in applied and skill-based domains. However, gaps in the PLO1 and PLO2 (knowledge and cognitive competencies) require additional instructional support. Survey analysis revealed that students were primarily motivated by career prospects and personal interest, while mathematical difficulties emerged as their greatest academic barrier. Descriptive patterns further showed that students motivated by career prospects and personal interest were more likely to report academic challenges (more than 63%). These included mathematical difficulty, gaps in foundational knowledge and the fast pace of learning. Others reported psychosocial challenges such as low confidence, poor time management, stress, and a lack of belonging. Regarding aspirations, most students (58.6%)*

planned to pursue science-related bachelor's degrees. A smaller group (24.1%) intended to switch to non-science fields, while others remained uncertain. Although 76% of students agreed that the cross-stream policy supported their plans, only 55% would stick to AS120 given a second chance. This shows some ambivalence. Overall, the findings suggest that the policy has broadened access and fostered pathways into science. However, sustained engagement in STEM requires stronger academic bridging in mathematics and science fundamentals. It is also a call for psychosocial interventions such as mentoring and confidence-building. Future research should adopt longitudinal, multi-institutional designs to assess long-term outcomes and identify best practices for cross-stream integration.

Keywords: *Cross-stream admission, academic performance, Program Learning Outcome, motivation, challenge*

1. INTRODUCTION

The Malaysian education system has long followed a streaming policy that channels secondary school students into either Arts or Science pathways. The structure was designed to align students with their academic strengths. However, since its implementation in 1967, the policy has not achieved its intended goals. Science-related fields continue to face low student representation, despite the national target of 60:40 Science-to-Arts enrolment. In 2020, 47% of students were enrolled in STEM subjects, but this dropped to 40.95% in 2021 and 40.94% in 2022. Although enrolments recovered to 45.73% in 2023 and further to 50.83% in 2024 (Gimino et al., 2024), participation remains below the national benchmark. Among the contributing factors are insufficient foundational preparation, perceptions of science as “difficult,” and limited awareness of STEM career opportunities (Idris et al., 2023; Phang et al., 2014; Vela et al., 2020; Wong et al., 2022).

While cross-stream admission policies at institutions such as Universiti Teknologi MARA (UiTM) have expanded access to science-based programs for Arts-stream students, concerns remain about their academic readiness, given limited prior exposure to advanced science and mathematics (Idris et al., 2023). A recent study by Julaihi and Mohamadin (2025) found that, with sufficient institutional support, Arts-stream students can achieve the program-aligned outcomes and succeed. However, the study primarily examined academic performance, leaving other aspects of the student experience underexplored.

This study addresses this gap by examining three dimensions of the cross-stream experience: (1) the academic performance of Arts-stream students in the Diploma in Science (AS120) program; (2) the motivations and challenges shaping their experiences; and (3) the aspirations guiding their educational and career pathways. Specifically, this study seeks to answer the following questions:

RQ1: How do Arts-stream students perform academically in AS120 with respect to Cumulative Grade Point Average (CGPA) and Program Learning Outcomes (PLO) attainment?
RQ2: What motivations and challenges influence their decision to pursue and persist in AS120?
RQ3: What are their aspirations, and how do they perceive the cross-stream policy in shaping their educational and career pathways?

2. LITERATURE REVIEW

2.1 ACADEMIC PERFORMANCE OF CROSS-STREAM STUDENTS

A central issue is whether Arts-stream students can meet the academic demands of science programs. Studies have shown that a lack of a strong foundation in the core sciences and mathematics hinders performance in higher education. Idris et al. (2023) highlighted that insufficient foundational knowledge in mathematics and science remains a significant barrier to STEM education in Malaysia. Similarly, Andrew et al. (2024) found that students without prior chemistry experience struggled significantly in general chemistry courses, underscoring the need for remedial support.

Recent findings from Julaihi and Mohamadin (2025) further reveal that Arts stream students faced the greatest difficulties in knowledge and cognitive domains (PLO1 and PLO2), indicating substantial struggles in foundational science skills. These challenges were associated with courses such as General Chemistry, Organic Chemistry, and Calculus, reflecting foundational knowledge in science. These findings raise critical questions about the long-term sustainability of cross-stream policies without structured interventions.

2.2 MOTIVATIONS FOR PURSUING SCIENCE PROGRAMS

Motivation plays a vital role in students' decisions to pursue science programs. It influences not only their interest but also their persistence and performance. At the secondary school level, students' intention to study science and pursue STEM careers is shaped by their attitudes, social influences, and self-efficacy, highlighting the importance of early engagement and sustained motivation (Tunku Ahmad et al., 2019; Razali et al., 2020). Motivation in science learning is closely tied to factors such as purpose, effort, belief, and emotion, which affect both emotional response and engagement (Glynn et al., 2007; Membiela et al., 2023).

Several theoretical perspectives help explain how motivation operates in science learning. Expectancy-Value Theory (Eccles & Wigfield, 2002) emphasises career and interest, while Self-Determination Theory (Ryan & Deci, 2000) focuses on autonomy, competence, and relatedness. Likewise, the Science Capital framework highlights how exposure to science experiences and networks shapes aspirations (Archer et al., 2015).

In the Malaysian context, motivation to pursue science programs is shaped by both internal and external factors. Career prospects, personal interest, social influence and institutional reputation remain consistent motivators for higher education choices (Julaihi & Mohamadin, 2024; Mohamadin & Julaihi, 2023; Sarkodie et al., 2020). Career goals remain the strongest motivator, as students often view science-related programs as pathways to professional success and stable employment (Mohamadin & Julaihi, 2023; Sarkodie et al., 2020). Personal interest enhances persistence and satisfaction, encouraging students to remain committed to their chosen field (Julaihi & Mohamadin, 2024). Social influences, including family encouragement, teacher support, and peer interactions, further strengthen students' motivation and confidence to pursue science pathways (Julaihi & Mohamadin, 2024; Mohamadin & Julaihi, 2023). Meanwhile, an institution's reputation and perceived quality also influence enrolment decisions, as students tend to associate well-regarded universities with better academic environments and career opportunities (Sarkodie et al., 2020).

2.3 CHALLENGES IN ADAPTING TO SCIENCE PROGRAMS

Arts-stream students encounter both academic and psychosocial challenges when entering science-based programs.

Academic challenges: Knowledge gaps, particularly in mathematics, scientific reasoning, and experimental methods, are among the most persistent challenges (Julaihi & Mohamadin, 2025; Ng, 2024; Aspin et al., 2022; Andrew et al., 2024; Abd Karim et al., 2023). Arts-stream students often come from curricula that emphasise humanities and arts rather than systematic scientific methods, making subjects like calculus and chemistry appear difficult and intimidating (Abd Karim et al., 2023). The pace of learning in science programs can feel overwhelming, especially when students must quickly grasp abstract and technical content (Julaihi & Mohamadin, 2025). Constraints on curriculum resources, such as heavy syllabus, insufficient teaching support, and limited laboratory access, hinder smooth transition into science programs (Azahar, 2023). Additionally, language barriers, particularly in mastering scientific English and technical terminology, further hinder comprehension and performance (Ng, 2024; Aspin et al., 2022). These difficulties are compounded by mathematics-related anxiety and limited exposure to scientific methodology, making it challenging for students to connect theory with practice (Aspin et al., 2022; Andrew et al., 2024).

Psychosocial challenges: Arts-stream students often report stress, anxiety, and time-management difficulties due to heavier workloads and increased academic demands (Ng, 2024). Confidence issues and feelings of inadequacy are also common, especially when students compare themselves to peers with stronger science backgrounds (Julaihi & Mohamadin, 2025; Aspin et al., 2022). Many of them are perceived as less capable in science-related subjects (Allvsionn, 2022). Such negative perceptions can lower self-esteem and create a sense of exclusion, discouraging active participation in learning and collaboration. These experiences align with the Science Capital framework (Archer et al., 2015), which explains that students with limited exposure to science-related knowledge, networks, and support often face identity and belonging issues that hinder persistence in STEM fields. Moreover, limited access to learning resources and insufficient preparatory exposure can further diminish confidence and engagement (Idris et al., 2023). Students who perceive science as difficult or "not for them" may develop avoidance behaviours and reduced self-efficacy, particularly in exam-oriented environments with minimal support (Esmail et al., 2024; Andrew et al., 2024).

2.4 FUTURE ASPIRATIONS

Students' future aspirations reflect more than just immediate program choices; they depend on whether cross-stream policies offer real opportunities, whether they receive adequate support during their studies, and whether their retrospective satisfaction with program outcomes reinforces their commitment to science careers. Many students see science careers as promising, particularly when they believe that education policies such as cross-stream or STREAM frameworks support creativity and interdisciplinary and broaden access (Ng, 2024). However, policies alone are insufficient. Mixed academic outcomes among Arts-stream students in programs such as AS120 indicate that supportive structures are needed to translate aspirations into sustainable success (Julaihi & Mohamadin, 2025).

Career goals, retrospective satisfaction, and perceptions of policy effectiveness influence what students plan after completing their diploma studies. For example, students whose expectations for employability and institutional reputation are met tend to be more satisfied and continue their studies; others may shift fields or enter the workforce if their expectations are not met. In Malaysia, many diploma students view continuing to a degree program as a means of upward mobility. However, their satisfaction with the diploma programs and clarity about future careers influence whether they pursue this path (Julaihi & Mohamadin, 2024). Many remain uncertain about their post-tertiary options, underscoring the need for better career guidance and clearer policy communication (Razali et al., 2020).

3. METHODOLOGY

3.1 RESEARCH DESIGN

This study employed a mixed-methods approach to evaluate both academic performance and experiences of Arts-stream students enrolled in AS120. The design combined quantitative analysis of students' academic performance records (CGPA and PLO attainment) with survey data on students' motivations, challenges and aspirations. Their perceptions of the cross-stream policy were also gathered in this study. The framework described in Figure 1 proposes that motivations drive students' entry into the Diploma of Science program, challenges shape their experiences, and these, in turn, influence their aspirations and views on the policy that enabled their access.
functionality.

The objective of this study is to design and evaluate a Packet Tracer–based troubleshooting assessment that measures students' practical diagnostic skills. The paper is organised as follows: Section 2 reviews relevant literature on troubleshooting pedagogy, simulation tools, and skill-based assessments. Section 3 describes the methodology, including the design of the Packet.

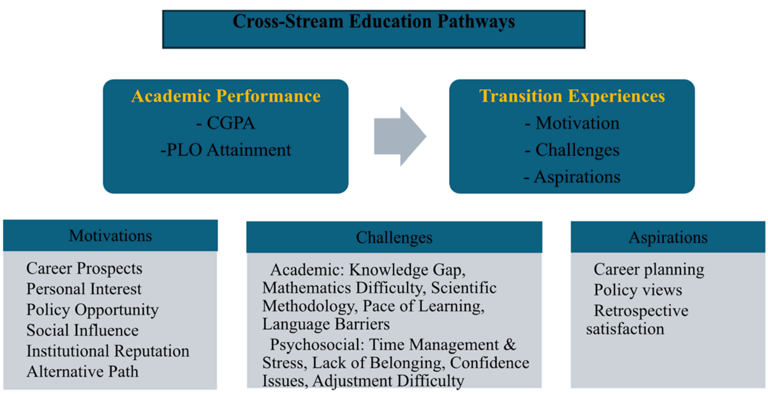

Figure 1. Conceptual Framework

3.2 PARTICIPANTS

The population involved all Arts-stream students admitted to AS120 at the UiTM Sarawak Branch for the October 2022 (20224) intake. The academic performance of 33 Arts-stream students was evaluated. However, only 29 students from this group were analysed, as 4 students failed to submit the Google Form survey.

3.3 INSTRUMENTS

This study includes two instruments:

1. Academic Performance Records: Students' CGPA and PLO attainment data were obtained from the university database to provide objective measures of performance. PLO attainment was assessed against program benchmarks to evaluate whether Arts-stream students achieved the intended learning outcomes.

2. Google Form Survey: A structured survey item was developed based on literature, as stated in Table 1, consisting of three main sections:
   Section A: Demographic Profile – Gender, Academic Status and CGPA.
   Section B: Motivations and Challenges – Likert-scale items assessing motivations for choosing AS120 and challenges faced during the study.
   Section C: Aspiration and Policy Perceptions – Career planning and reflections on cross-stream policy and program choice.

Construct	Item	Literature
1. Motivations	• Career Prospect • Personal Interest • Policy Opportunity • Social Influence • Institutional Reputation • Alternative Path	• Career Aspiration, Personal Interest, People Influences (Julaihi & Mohamadin, 2024) • Career Aspiration, Personal Interest, Social Influence, Institutional Reputation (Mohamadin & Julaihi, 2023) • Reputation of Institution, Personal Interest, Career Desire, Social Influence (Sarkodie et al., 2020)
2. Challenges	• Knowledge Gap • Mathematics Difficulty • Scientific Methodology • Pace of Learning • Language Barriers • Time Management & Stress • Lack of Belonging • Confidence Issues • Adjustment Difficulty	• Knowledge gap, Pace of Learning, Confidence Issues, Adjustment Difficulty (Julaihi & Mohamadin, 2025) • Knowledge Gap, Mathematics Difficulty, Language Barriers, Time Management & Stress, Confidence Issues, Adjustment Difficulty (Ng, 2024) • Knowledge Gap, Mathematics Difficulty, Scientific Methodology, Language Barriers, Confidence Issues, Adjustment Difficulty (Aspin et al., 2022) • Knowledge Gap, Confidence Issues, Adjustment Difficulty, Scientific Methodology (Andrew et al., 2024)
3. Aspirations	• Career planning • Policy views • Retrospective satisfaction	• Career prospect, cross-stream policy views and program satisfaction (Julaihi & Mohamadin, 2024) • Scientific Career, SHS policy views and program satisfaction (Ng, 2024)

Table 1. Development of survey items based on the literature

To ensure the instrument's reliability, the internal consistency of survey items on motivations and challenges was assessed using Cronbach's Alpha, which ranges from 0 to 1. As shown in Table 2, the resulting reliability coefficient ranged from 0.795 to 0.856 (>0.70), indicating acceptable internal consistency and thus confirming the instrument's reliability in measuring the intended constructs.

Constructs	No. of items	Cronbach's Alpha
Motivation for choosing AS120	6	0.795
Challenges during AS120 studies	9	0.856

Table 2. Cronbach's alpha

3.4 DATA COLLECTION

Students' academic performance data (CGPA and PLO attainment) were collected from the UiTM database with permission from the Academic and International Affairs Division of UiTM Sarawak. Survey data were collected online via a Google Form, distributed to students through institutional communication channels. Participation was voluntary, and informed consent was obtained prior to data submission.

3.5 DATA ANALYSIS

Quantitative data from students' academic performance records (CGPA and PLO attainment) were analysed using descriptive statistics to evaluate the performance of Arts-stream students and determine whether they met program expectations. Survey responses were similarly analysed descriptively to examine students' motivations, challenges and aspirations. In addition, students' perspectives on the cross-stream policy and their retrospective on whether to choose the same program again if given the chance were also investigated. Finally, responses to open-ended questions were analysed thematically to capture nuanced reflections on policy impacts and overall program experiences.

4. RESULTS AND DISCUSSION

4.1 ARTS-STREAM STUDENTS' PROFILES

From the 182 students admitted into AS120 at UiTM Sarawak for the October 2022 (20224) intake, 43 were Arts-stream students. Table 3 summarises the profiles of these students. The majority were female (74.4%), reflecting a gender imbalance in cross-stream enrolments. In terms of academic status, just over half (51.2%) graduated on time within five semesters, while 16.3% required six semesters and 9.3% were still enrolled in their seventh semester at the time of reporting. However, 11.6% quit, and another 11.6% were dismissed. CGPA data, available for 33 students, showed that only 3.0% attained a CGPA of 3.50 and above, while most achieved between 2.50–2.99 (48.5%) or 3.00–3.49 (39.4%), and a small proportion (9.1%) fell within the lowest band (2.00–2.49). Taken together, these findings indicate that while most Arts-stream students completed the program and attained average academic outcomes, relatively few excel academically, and the attrition rates highlight the need for additional academic and psychosocial support. The results are consistent with Julaihi and Mohamadin (2025), who found that admitting Arts stream students to science programs is academically viable, provided that appropriate academic support is in place. Only 8 students (27.6%) selected AS120 as their first choice, indicating that fewer than one-third of students entered the program as their top preference. The majority, 19 students (65.5%), chose AS120 as an alternative, suggesting that for most, the program was their secondary option. A small minority of 2 students (6.9%) stated that AS120 was not among their original program choices.

Profiles	Total
Gender (n=43)	
Female	32 (74.4%)
Male	11 (25.6%)
Academic Status (n=43)	
Graduated with Vice Chancellor Award	0 (0.0%)
Graduated on time (5 semesters)	22 (51.2%)
Graduated (6 semesters)	7 (16.3%)
Ongoing (semester 7)	4 (9.3%)
Quit	5 (11.6.%)
Dismissed	5 (11.6.%)
CGPA (n=33)	
3.50 and above	1 (3.0%)
3.00 to 3.49	13 (39.4%)
2.50 to 2.99	16 (48.5%)
2.00 to 2.49	3 (9.1%)
AS120 as:	
First Choice: Top preference.	8 (27.6%)
Alternative Choice: Secondary option.	19 (65.5%)
Not a Choice: Not originally chosen.	2 (6.9%)

Table 3. Profiles of Arts-stream students admitted into AS120

4.2 CGPA ACHIEVEMENT AND PLO ATTAINMENT

Table 4 presents the descriptive statistics for CGPA achievement and PLO attainment among Arts-stream students. The students' CGPA ranged from 2.36 to 3.66, with a mean of 2.96 (SD = 0.27), indicating overall performance near the borderline between second class upper (3.00-3.49) and second class lower (2.50-2.99). Only one Art-stream student from this cohort achieved the first class with a CGPA of 3.66. Overall, these findings suggest that Arts-stream students exhibit moderate academic achievement, as indicated by their CGPA. This aligns with evidence that prior exposure to science subjects provides a strong advantage in higher education, as reported by many studies. For instance, Julaihi and Mohamadin (2025) reported that Arts stream students enrolled in the Diploma in Science program faced significant challenges in core courses such as General Chemistry, Organic Chemistry and Calculus, highlighting the critical role of prior preparation in scientific disciplines.

	N	Minimum	Maximum	Mean	Std. Deviation
CGPA	33	2.36	3.66	2.9645	.27037
PLO1 Mark (Knowledge)	33	38	80	52.58	8.979
PLO2 Mark (Cognitive)	33	38	80	52.88	11.420
PLO3 Mark (Practical Skills)	33	78	86	82.70	2.038
PLO4 Mark (Intrapersonal Skills)	28	79	99	87.79	4.756
PLO5 Mark (Communication Skills)	33	61	84	71.06	5.043
PLO6 Mark (Digital Skills)	33	75	89	83.55	3.113
PLO7 Mark (Numerical Skills)	33	70	92	84.03	6.242
PLO8 Mark (Leadership, Autonomy, and Responsibility)	33	75	89	81.82	3.432
PLO9 Mark (Personal Skills)	33	64	88	74.36	5.578
PLO10 Mark (Entrepreneurial Skills)	33	54	90	78.64	6.841
PLO11 Mark (Ethics and Professionalism)	33	77	92	84.39	4.054

Table 4. Descriptive Statistics of Arts Stream Students' CGPA and PLO Attainment

In terms of PLO attainment, variation was evident across different domains. Lower mean scores were recorded for PLO1 (Mean = 52.58, SD = 8.98) and PLO2 (Mean = 52.88, SD = 11.42), which are typically associated with foundational knowledge and cognitive skills. By contrast, higher mean scores were achieved in applied and higher-order domains such as PLO3 (Mean = 82.70), PLO6 (Mean = 83.55), PLO7 (Mean = 84.03), PLO10 (Mean = 78.64), and PLO11 (Mean = 84.39), suggesting stronger performance in practical, problem-solving, and integrative skills. The relatively high attainment in PLO4 (Mean = 87.79) and PLO8 (Mean = 81.82) further highlights the students' ability to meet performance expectations in discipline-specific applications. Although they can meet or exceed PLO benchmarks in applied and skill-based areas, gaps remain in PLO1 and PLO2 (knowledge and cognitive domains) that require additional instructional support

.

Table 5 and Figure 2 highlight the distribution of course failures across different PLOs among Arts-stream students, revealing clear patterns of academic difficulty. Most students struggled with PLO1 and PLO2, which correspond to foundational knowledge and cognitive skills. Of 33 students, 31 failed at least one course mapped to PLO1, with individual students failing 3 to 16 courses, underscoring persistent challenges in mastering basic science and mathematics concepts. A similar trend was observed for PLO2, where 31 students also experienced failures, though at a lower intensity (1 to 6 courses failed). By contrast, failures were much less frequent in the higher-order and applied PLOs. For example, only a handful of students failed courses associated with PLO3 (n = 4), PLO5 (n = 3), PLO7 (n = 2), PLO8 (n = 1), PLO9 (n = 2), and PLO10 (n = 4), with each case involving a single course.

The pattern suggests stronger student performance in applied and integrative tasks but weaker outcomes in theory-driven, content-heavy areas. The findings align with Julaihi and Mohamadin (2025), who reported higher failure rates among Arts-stream students in PLO1 and PLO2, which reflect substantial challenges in foundational science skills. They are further supported by Eitemüller and Habig (2020), who observed that students lacking prior exposure to essential scientific concepts are more likely to struggle in entry-level courses, unless bridging support is provided. Similarly, Leong et al. (2021) highlighted that misalignment between secondary and tertiary curricula in science subjects can contribute to early academic difficulties. Taken together, these results point to a critical gap: Arts-stream students are capable of developing applied scientific competencies but face substantial barriers in acquiring the foundational disciplinary knowledge that underpins advanced learning, reinforcing the need for stronger bridging and remedial support in early semesters.

	N	Number of Students Failed	Minimum of Courses Failed	Maximum of Courses Failed
PLO1	33	31	3	16
PLO2	33	31	1	6
PLO3	33	4	1	2
PLO5	33	3	1	1
PLO7	33	2	1	1
PLO8	33	1	1	1
PLO9	33	2	1	1
PLO10	33	4	1	1

Table 5. Number of Arts-stream students failing courses by PLO

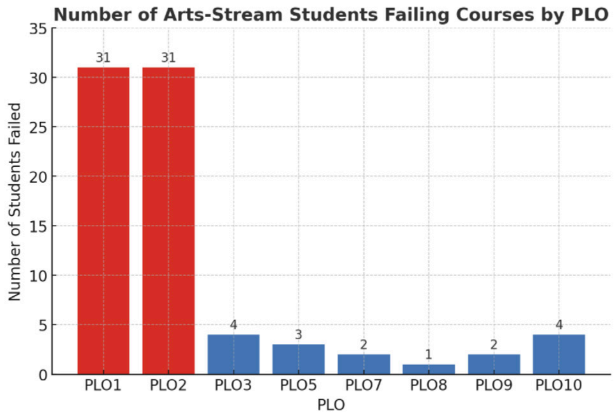

Figure 2. Number of Arts-stream students failing courses by PLO

4.3 MOTIVATIONS AND CHALLENGES

Tables 6 and 7 present a descriptive analysis of students' motivations and challenges during their AS120 studies. The results revealed that students' strongest motivation for enrolling in AS120 was personal interest in science (M = 4.00, SD = 0.76), followed by the policy opportunity enabling Arts students' entry into science (M = 3.93, SD = 1.07) and career prospects (M = 3.90, SD = 0.77). Institutional reputation (M = 3.79, SD = 1.01) was moderately influential, while the social influence (M = 3.62, SD = 0.82) and enrolling as an alternative pathway (M = 3.62, SD = 1.05) were the least endorsed. Overall, the results suggest that intrinsic motivation and policy accessibility are the most salient drivers of program choice, with external or fallback reasons playing a secondary role.

Meanwhile, students' greatest academic challenges were the lack of foundational knowledge in science (M = 3.93, SD = 1.16) and mathematical difficulty (M = 3.79, SD = 1.18). Other academic barriers, such as pace of learning (M = 2.97, SD = 1.30), scientific methodology (M = 2.72, SD = 1.07), and language proficiency (M = 2.52, SD = 1.06), were reported less strongly. With respect to psychosocial factors, the most prominent challenges were feelings of not belonging among peers in science (M = 3.41, SD = 1.21) and confidence issues (M = 3.34, SD = 1.17). Stress due to workload (M = 2.86, SD = 1.03) and adjustment difficulties (M = 2.97, SD = 1.18) were rated lower. Overall, these findings suggest that cross-stream students are most hindered academically by knowledge and math gaps and, psychosocially, by belongingness and confidence issues.

Motivation Item	M	SD
Career Prospects: I believe AS120 offers better job opportunities and higher learning potential.	3.90	0.77
Personal Interest: I have a genuine passion and curiosity for science subjects.	4.00	0.76
Policy Opportunity: The new policy allowing Arts-stream students to enter science programs.	3.93	1.07
Social Influence: I was strongly encouraged by family, teachers, or peers.	3.62	0.82
Institutional Reputation: I wanted to study at UiTM, and this was the best available option for me.	3.79	1.01
Alternative Path: It was an alternative to my first-choice program, which I did not get into.	3.62	1.05

Note. Ratings were based on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

Table 6. Students' Motivations for Choosing AS120 (N = 29)

Challenge Item	M	SD
Academic Challenges		
Knowledge Gap: Lack of prior science subject knowledge.	3.93	1.16
Mathematics Difficulty: Struggling with mathematical concepts and calculations.	3.79	1.18
Scientific Methodology: Difficulty in understanding and applying the scientific method.	2.72	1.07
Pace of Learning: The course pace was too fast.	2.97	1.30
Language Barrier: Difficulty with English or technical terminology used in science subjects.	2.52	1.06
Psychosocial Challenges		
Time Management & Stress: unable to balance the heavy workload, leading to constant stress and anxiety	2.86	1.03
Lack of Belonging: Feeling out of place or isolated among peers with a science background.	3.41	1.21
Confidence Issues: Struggling with self-doubt or feeling like an "imposter syndrome".	3.34	1.17
Adjustment Difficulty: Finding it hard to adapt to different learning styles and cultures.	2.97	1.18

Note. Ratings were based on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

Table 7. Academic and Psychosocial Challenges (N = 29)

When asked to select their single most important motivation for enrolling in AS120 (see Table 8), career prospects were the top choice (44.8%), followed by personal interest in science (37.9%). Fewer students selected the alternative path (13.8%) or social influence (3.4%). Although "alternative path" was the least endorsed (see Table 6), a few students still chose it as their main motivation. This shows that while most did not see AS120 as a fallback, for some, the chance to enter through this route was personally the most important factor.

Motivation	Frequency	Percent (%)
Career Prospects	13	44.8
Personal Interest	11	37.9
Alternative Path	4	13.8
Social Influence	1	3.4

Table 8. Most Important Motivation for Enrolling in AS120 (N = 29)

When asked about their greatest challenge (see Table 9), over one-third (34.5%) identified mathematical difficulty, with 13.8% reporting knowledge gaps and confidence issues. Other challenges, such as the pace of learning, time management & stress, and a sense of not belonging, each accounted for 10.3% of responses. In comparison, 3.4% cited scientific methodology and difficulty adjusting, respectively. The findings reinforce that while students were motivated primarily by career prospects and personal interest, they perceive mathematics as their greatest barrier to success. This is consistent with Aspin et al. (2022), Idris et al. (2023) and Ng (2024), who all reported mathematics as a persistent obstacle in STEM learning. International evidence further supports this pattern, with Eitemüller and Habig (2020) and Leong et al. (2021) showing that inadequate prior preparation and curricular misalignment contribute to early struggles in mathematics-intensive courses.

Challenge	Frequency	Percent (%)
Mathematics Difficulty	10	34.5
Knowledge Gap	4	13.8
Confidence Issues	4	13.8
Pace of Learning	3	10.3
Time Management & Stress	3	10.3
Lack of Belonging	3	10.3
Scientific Methodology	1	3.4
Adjustment Difficulty	1	3.4

Table 9. Greatest Challenge Faced in AS120 (N = 29)

A cross-tabulation of students' primary motivations and their greatest challenges (Tables 10 and 11) revealed clear patterns. Among those motivated by career prospects, the majority (69.2%) reported academic challenges, most notably mathematical difficulty, knowledge gap and the pace of learning. In comparison, 30.8% reported psychosocial challenges such as confidence issues, time management & stress, or a lack of belonging. Similarly, students motivated by personal interest were more likely to cite academic challenges (63.6%), while only 36.4% identified psychosocial barriers.

Although statistical significance was not reached due to a small sample size, the observed pattern suggests that motivation may shape the nature of challenges experienced by cross-stream students. This pattern resonates with earlier work showing that limited preparation in science and mathematics hampers student success (Aspin et al., 2022; Idris et al., 2023; Ng, 2024) and insufficient prior exposure and curriculum misalignment contribute to early struggles (Eitemüller & Habig, 2020; Leong et al., 2021).

Although psychosocial issues are less prevalent than academic barriers, Ng's (2024) findings align with the idea that psychosocial factors influence persistence and adjustment, even when academic difficulties dominate. Together, this suggests that cross-stream students require not only academic bridging support but also interventions that build confidence, manage stress, and foster a stronger sense of inclusion.

Motivation→ Challenge ↓	Career Prospects	Personal Interest	Alternative Path	Influence of Others	**Total**
Mathematics Difficulty	6	3	1	0	10
Knowledge Gap	2	2	0	0	4
Confidence Issues	2	1	1	0	4
Pace of Learning	1	2	0	0	3
Time Management & Stress	1	1	1	0	3
Lack of Belonging	1	2	0	0	3
Scientific Methodology	0	0	1	0	1
Adjustment Difficulty	0	0	0	1	1
Total	13	11	4	1	29

Table 10. Motivations vs Challenges

Type of Challenges → Motivation ↓	Academic Challenges	Psychosocial Challenges	**Total**
Career Prospects	9	4	13
Personal Interest	7	4	11
Alternative Path	2	2	4
Social Influence	0	1	1
Total	18	11	29

Table 11. Motivation vs Type of Challenges

As shown in Table 12, students who selected AS120 as their first choice were mostly motivated by personal interest (50%), whereas those who chose it as an alternative were mostly motivated by career prospects (47.4%). In contrast, the small number of students who did not choose AS120 showed motivations tied to career prospects and social influence.

Choice → **Motivation ↓**	First Choice	Alternative Choice	Not a Choice	**Total**
Career Prospects	3	9	1	13
Personal Interest	4	7	0	11
Alternative Path	0	1	0	1
Social Influence	1	2	1	4
Total	8	19	2	29

Table 12. Motivation vs Choice

In terms of challenges (see Table 13), mathematics difficulty was the most frequently cited across all groups, particularly dominant among those who did not choose AS120 (100%). First-choice students struggled mainly with mathematics (37.5%), but also reported time management, pace, and confidence as secondary issues. Alternative choice students faced a broader range of academic and psychosocial challenges, suggesting weaker preparation and integration into the program.

Choice → **Challenge ↓**	First Choice	Alternative Choice	Not in Choice	**Total**
Foundational Knowledge	1	3	0	4
Mathematical Difficulty	3	5	2	10
Scientific Methodology	0	1	0	1
Pace of Learning	1	2	0	3
Time management & Stress	1	2	0	3
Lack of Belonging	1	2	0	3
Confidence Issues	1	3	0	4
Adjustment Difficulty	0	1	0	1
Total	8	19	2	29

Table 13. Challenges vs Choice

4.4 FUTURE ASPIRATIONS

Table 14 presents the descriptive analysis of students' immediate plans and career vision after completing their AS120 studies. Analysis revealed that the majority (58.6%) planned to pursue a bachelor's degree in a science-related field, with smaller groups aiming for non-science degrees (24.1%), seeking employment (6.9%), or taking a gap year before deciding on next steps (10.3%). Regarding career vision, 34.5% aspired to science-related careers, 27.6% to interdisciplinary fields, 20.7% to non-science careers, and 17.2% were uncertain.

	Frequency	Percentage
Immediate Plan		
Pursue a science-related degree program	17	58.6
Pursue a non-science degree program	7	24.1
Seek employment	2	6.9
Take a gap year before deciding	3	10.3
Long-term Career Vision		
Science-related career	10	34.5
Interdisciplinary career	8	27.6
Non-science career	6	20.7
Uncertain	5	17.2

Table 14. students' immediate plans and long-term career vision

Regarding students' perceptions of the university's policy of offering AS120 to Arts-stream students, 38% agreed, 38% were neutral, and 24% disagreed (see Figure 3). By contrast, a stronger consensus was observed regarding the broader cross-stream policy, with 76% agreeing or strongly agreeing that it had enabled their plans (see Figure 4).

When asked whether they would make the same choice, given a second chance, 55% said they would still enrol in AS120, 21% were uncertain, and 24% said they would likely choose other diploma programs (see Figure 5). Taken together, these findings suggest that while the policy has successfully broadened access and fostered science pathways for Arts-stream students, ambivalence and regret are present among a minority of students. This underscores the need for enhanced academic and psychosocial support to ensure sustained engagement and long-term commitment to STEM trajectories.

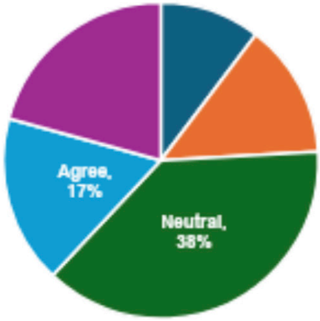

Figure 3. Perceptions of the University Policy to Offer AS120 to Arts Stream Students

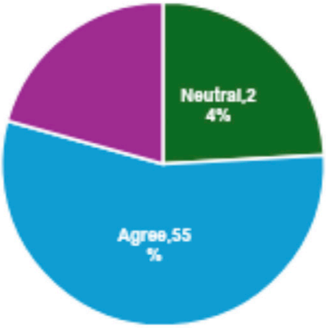

Figure 4. Perceptions of Cross-streams Policy Impact on Future Plans

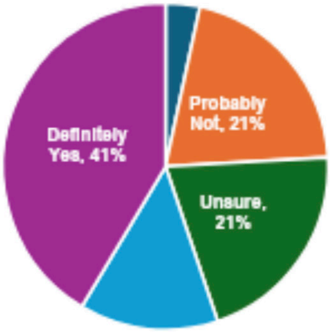

Figure 5. Counterfactual Choice if Allowed to Decide Again

Most students who indicated they would “definitely” or “probably” choose AS120 again emphasised intrinsic interest, academic foundations, and positive experiences. Several highlighted a strong passion for science and the program’s role in preparing them for advanced study:

“It gives me the foundation to pursue in Chemistry. I have a strong passion for Chemistry, and this program prepares me with the essential knowledge and skills to continue further in this field.”

“It provides wide opportunities to continue into a degree.”

Others valued the supportive social environment that helped them pursue their goals and expressed gratitude for discovering their potential in the science stream:

“Even though it was not my first choice, I am having fun while studying this course. My classmates and lecturers were very supportive. When I felt down, my friends comforted me. It was a great experience for me, and this course is the key to pursue my dream.”

“I was interested in learning science since I was in high school. I am grateful for having the chance to know my ability in learning and adapting in the science stream.”
Sometimes it is fun to challenge yourself with something you do not know.”

These views align with Julaihi & Mohamadin (2024), who found that personal interest and program satisfaction are critical drivers of persistence, and Wong et al. (2022), who emphasised that clear pathways to STEM careers sustain student motivation.

In contrast, students who were “unsure” or indicated they would “probably not” choose AS120 reflected struggles with background preparation, program fit, and career relevance. Some admitted that while Science offered valuable new skills, pursuing the Arts is more natural. Others admitted to ongoing struggles and difficulty of adapting to the program without prior preparation, while others expressed frustration over limited job prospects:

“I am unsure because while my background was in Arts, I also find Science interesting and challenging. Studying Science has given me new knowledge and skills, but at the same time, I sometimes feel that continuing in the Arts stream might have been more natural for me.”

“I could see myself choosing either path, and I have not yet gathered enough clarity or personal conviction to commit to one. I want to consider carefully before making a decision.”

“I can see myself handling Science subjects decently at best. I am tempted to quit the course, but I also feel like that would be a waste.”

“I personally think that I have more potential in other courses, but I have currently developed an interest in applied science, though I do find myself struggling sometimes.”

“Probably not because the jobs that I applied for got rejected, and they require experience. Also, a Diploma in Science is too general for most of the jobs available.”

“Since I do not have any basic knowledge in the science stream, I survived this course because I have a family member related to this field who helped me a lot. I would choose a different program if I could turn back time to pursue what I am passionate about.”

“For a non-science stream student, it is kind of hard to adapt well to science”

These concerns are consistent with Andrew et al. (2024) and Idris et al. (2023), who reported that knowledge gaps and weak foundations are significant barriers in STEM education, and align with Mohamadin and Julaihi (2023), who found that misalignment between program content and career opportunities can lead to student dissatisfaction.

Tables 13 and 14 present the benefits and challenges of the cross-stream policy from students' perspectives. This policy allows students to foster new passions and interests in science (86.2%), ensuring equitable access to science education (72.4%), and expanding career opportunities (58.6%). In terms of the challenges, the students highlighted foundational gaps and a lack of tailored teaching approaches as the most pressing issues (69.0%).

Benefits	Frequency	Percent (%)
Allows students to foster new passions and interests	25	86.2
Provides equitable access to science education for all students	21	72.4
Opens a wider range of high-demand career paths for Arts students	17	58.6
Helps meet national goals for a more scientifically literate workforce	8	27.6
Creates a more diverse and interesting classroom environment	7	24.1

Table 13. Benefits of the Cross-stream policy (N = 29)

Challenges	Frequency	Percent (%)
Arts students need better foundational preparation (e.g., a bridging program)	20	69.0
Risk of students struggling excessively without adequate support systems	20	69.0
Academic advisors and lecturers need more training to support Arts students	16	55.2
Teaching methods need to adapt to diverse learning backgrounds	12	41.4
Policy might not be well-understood/supported by all staff	6	20.7

Table 14. Challenges of the Cross-stream policy (N = 29)

Several students called for bridging programs and extra classes to introduce the basics of Biology, Chemistry, Physics, and Mathematics before diving into advanced topics. Others stressed the need for step-by-step teaching and a slower pace and suggested a peer tutoring or mentorship program. Emotional and social support were also emphasised, with students urging lecturers to avoid discriminatory attitudes:

Informant 1: "The faculty could support Arts students by offering more interactive and practical learning approaches, such as laboratory-based activities, tutorials in small groups, and mentorship sessions. This would make complex science topics easier to understand and keep students motivated. Encouraging collaboration between Science and Arts background students can also create a supportive learning environment."

Informant 2: "The faculty can help students by preparing and teaching them from the very basic science backgrounds so that they have the ideas about all topics that they will learn later on."

Informant 3: "To not discriminate and talk down on students from the Art stream because it can cause their confidence level to be down, keep an open mind during their teaching, and be patient when seeing arts students ask for help or even struggle, especially during tests and learning in the classroom. Lecturers need to show that they want to help students. As simple as giving time to students asking questions during non-lecture time."

Informant 4: "Lecturers can try to change their teaching methods… and not go too fast on the learning pace so that these students will not feel left out or lost."

Informant 5: "Peer Tutoring, which pairs students from the sciences and arts. I personally benefited from this approach as I received great support from my science friends."

Informant 6: "I suggest implementing a mentorship program where Arts students are paired with seniors who have successfully transitioned into the Science stream. This will provide guidance, motivation, and real-life insights to help them adapt better and feel more supported."

These responses align with Julaihi & Mohamadin (2025), who stressed that academic and affective support systems are vital for student success, and Idris et al. (2023), who pointed to pedagogical innovation as key to sustaining STEM participation.

5. CONCLUSION

This study concludes that the cross-stream admission policy at UiTM has successfully expanded access to science education and provided alternative pathways for Arts-stream students to engage in STEM disciplines. The findings showed that these students achieved moderate CGPA scores and satisfactory attainment in most PLO, particularly in applied and skill-based domains. However, persistent weaknesses in foundational knowledge and cognitive competencies (PLO1 and PLO2) highlight the need for enhanced instructional support in mathematics and basic sciences.

Students were primarily motivated by career prospects and personal interest, but faced notable academic challenges, including mathematical difficulties, gaps in foundational knowledge, and the fast pace of learning (more than 63%). Psychosocial issues such as low confidence, poor time management, stress, and lack of belonging further affected their academic adjustment.

In terms of aspirations, 58.6% planned to continue in science-related bachelor's degrees, 24.1% intended to switch to non-science fields, and the rest remained uncertain. While 76% agreed that the cross-stream policy supported their future goals, only 55% would choose the same program (AS120) again, indicating mixed feelings about their experience.

Overall, the cross-stream policy has proven academically viable and socially inclusive. However, its long-term success requires structured academic bridging, adaptive pedagogical approaches, and holistic support systems that address both cognitive and affective needs.

6. SUGGESTIONS

Future research should use longitudinal and multi-institutional approaches to assess the long-term outcomes of cross-stream students in science programs. Comparative studies between Science- and Arts-stream students can help determine how prior preparation affects success and retention. Qualitative studies exploring students' experiences and motivation would enrich the understanding of the challenges of cross-stream transitions. Moreover, studies on the bridging modules, peer mentoring, and inclusive teaching strategies are also recommended to improve institutional practices and policy reforms. Such evidence-based insights will help strengthen and sustain cross-stream integration in higher education.

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9. AUTHORS' CONTRIBUTION

The authors confirm the equal responsibilities for this paper and approve the final version.

10. CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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Global Learning: Innovative Educational Practice

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Abstract: *Access to study abroad in higher education is still limited to students from affluent backgrounds or with outstanding academic results. To make this experience more inclusive for many, internationalisation in higher education has shifted its paradigm in the last few decades from the conventional demarcation of student mobility abroad to internationalisation at home (IaH) and internationalisation of the curriculum (IaC). Global learning is a high-impact educational practice that provides students with unique, authentic learning experiences beyond the classroom. This innovative teaching approach brings about a paradigm shift in classroom delivery and helps students explore different worldviews, cultures, and life experiences, globally and boundlessly. Global learning fosters intercontinental awareness and appreciation of diversity. In this session, students will gain extensive knowledge and understanding from experts and industry players overseas about the topics they learn in class.*

Keywords: *Global Learning, High Impact Educational Practice, Experiential Learning*

1. INTRODUCTION

High-impact practices (HIPs) are educational opportunities designed to increase not only students' retention and grades but also the number of graduates (Finley, 2013). Designed by George Kuh, based on his work with large datasets from the National Survey of Student Engagement (NSSE), these practices include first-year seminars, common intellectual experiences, learning communities, writing-intensive courses, collaborative projects, undergraduate research, diversity/global learning, service-learning, internships, and capstone courses.

Participation in these practices has been shown to impact the academic experiences of underserved students significantly and to promote equitable outcomes across the institution (Kuh, 2008). Students can transfer classroom content (or knowledge they learn in the classroom) into their lives, interact with people from different cultures, strengthen their connections with their faculty, and report deeper learning experiences from participating in multiple well-designed, accessible HIPs.

High-impact learning happens when students are actively engaged in the educational process and when their learning extends beyond the classroom to be applied in their personal and work lives. Students engaged in high-impact learning often see improvements in grade point averages, graduate on time, and are more engaged in their education.

2. RESPONSIVE LEARNING IN GLOBAL LEARNING

A shift towards global education is not new, as learning experiences that extend beyond national borders have taken many forms. In response to the acceleration of online learning during the Covid-19 pandemic, Universiti Teknologi MARA (UiTM) has advocated for a move toward a more global education for all students to create a more engaging and responsive learning environment. Through global learning initiatives, UiTM immerses its students in culturally diverse activities, with lecture delivery by multi-racial educators and industry players with sound knowledge from diverse backgrounds and cultures. The Association of American Colleges and Universities has described global learning initiatives as a means for students to learn about the diversities and commonalities among the world's peoples, cultures, nations, and regions (Association of American Colleges and Universities [AAC&U], 2018). Therefore, culturally-responsive teaching is integral to any global learning (Rego, 2018). Students can gain learning experiences by accessing global content on history, people, and cultural events from countries around the world through global learning platforms. Ultimately, engaging students in this way helps them embrace the diversity around them and prepares them to be more responsive to the dynamics of the global learning environment and to enter the global workforce.

Although the composition of students at UiTM may not fully enable the realisation of culturally responsive teaching, as the students are Bumiputras, the global learning experiences they have gained could make them more responsive and responsible learners. Global learning practices, through access to shared global knowledge, allow students, particularly those from marginalised groups, to meet their cognitive and social-emotional needs and thus expand their potential as learners. They will also benefit most from the cultural dimension of this global learning experience.

Global learning through collaborative efforts at UiTM promotes internationalisation of the curriculum and fosters a cross-cultural environment. Internationalisation of the curriculum does not solely refer to outbound student mobility. Nowadays, it can mean "internationalisation at home", aimed at providing benefits to all students (Leask, 2015). By undertaking global learning activities through collaborative teaching and learning, UiTM has increasingly recognised the need to involve more students in internationalisation. Hence, through global learning, it is hoped that this endeavour will help develop students into responsible global citizens and, indirectly, impact the local community and global society. In addition, global learning practices encourage cross-cultural knowledge by sharing and addressing issues from different perspectives. Students from different countries come together in the learning process and are productive in influencing one another.

To optimise learning through global learning practices, reflection on universal instruction is supported by administering questionnaires for feedback after each session. Feedback on the session content is essential to ensure it meets the learning needs of all students and to make informed, responsive decisions about the implementation and outcomes of the global learning sessions. Reflecting on student progress will definitely support student learning and, in turn, help educators design a more responsive learning environment and plan global learning practices in the future.

Student feedback on global learning sessions was overwhelmingly positive. Regarding knowledge acquisition, many participants in the global learning session felt that the sessions provided a lot of information. In one session, their responses were as follows:

I learnt about the environment in Germany and more information about insurance in Germany.

"Actually, I learned more new things today."

"I learned about it in German."

"They provide living costs for the unemployed, not like in Malaysia, which is based on lots of perspectives."

"In Germany, they have lots of famous international firms or industries that provide export items into Asia and other countries that Malaysia does not have. In Malaysia, we follow the industry but cannot make one."

"From the talk, I know the current social system in Germany and its economy."

"I learned that we are all the same and equal. However, out in the world, there is countless diversity."

Feedback from another participating class:
"I have learned a lot about Indonesian culture."
"I have learnt the background of Indonesia and the status of English there."
"I learned about how beautiful Indonesia is and its culture."
"I have learnt a lot about Indonesia's culture and the use of English in the country."
"I learnt a lot about Indonesian cultures and their way of living."
"I have learnt about the status of English in Indonesia. It was new knowledge for me."

Based on the comments, the students who participated greatly benefited from the learning sessions. Although there were variations in their responses, they definitely have enhanced their learning. They were in direct contact with different cultures, focusing on what they could gain during the global online session. Not all students will learn and reflect on the same thing, as they possess different focuses and perspectives, indicating that they are responsible for their own learning. However, the implications would mainly concern cultural diversity, which they will bring forward in their globalised future. Clearly, global learning has expanded each student's cultural horizons and knowledge, empowering them to enhance their global competence.

3. METHOD/ DATA/PRACTICE

The importance of global learning as a response of higher education institutions to globalisation cannot be overstated. Students should acquire it as part of their academic experience at colleges and universities as a result of the internationalisation of higher education (Hovland, 2014; Olson et al., 2006; Ruscio et al., 2015). (Hovland, 2014; Olson et al., 2006; Ruscio et al., 2015). Students are required to develop knowledge, skills, and attitudes (KSAs) about the external world and their internal selves in their daily lives across local and global communities to achieve the essential learning outcome of global learning. This is because global learning is the essential learning outcome.

3.1 THE FORM OF GLOBAL LEARNING SESSIONS

There are two forms in which global learning sessions can be conducted:

- Classes may incorporate globally focused or comparative perspectives to examine issues through a global lens. Faculty may invite speakers who explore global diversity. Course activities, projects, teams, online intercultural collaborations, and assignments may support engagement with global perspectives and/or action on global issues; or

- Virtual learning experiences with a global focus can transcend place-based boundaries—allowing connection with peers around the world through technology or participation in international internship experiences without leaving home.

3.2 THE METHODS TO START A GLOBAL LEARNING SESSION IN THE CLASSROOM.

There are three phases to starting a global learning session in the classroom. The first phase is planning global learning. This can be done through:

- studying the syllabus
- knowing your students
- matching the topic/subtopic to the speaker's expertise
- discussing and getting approval from the management (if necessary)
- firming up details

The second phase is the implementation (virtual/online) phase. Here, the lecturers need to:

- prepare your students
- prepare your lessons
- have a pre-discussion/meeting with your invited speaker
- set the time and duration
- run the lesson

The final phase is to review and improve the session. This can be done by doing the following:

- get feedback from students, have a post-session discussion
- send a "thank you" email to your colleague/invited speaker
- self-reflect, self-evaluate, improve, and plan your next session

Based on these evaluation phases, any system may "create a functional match between what the environment provides and what the actor can and desires to perform" (Thelen & Smith, 1994, p. 44). This is illustrated in Figure 1 below:

Figure 1. Methods to start a global learning session

Global learning opportunities focus on cultivating skills, knowledge, abilities, and networks to prepare students to engage in the challenges and opportunities of our highly interconnected world. Broad global learning goals guide learning, and each goal has a set of outcomes that demonstrate what students will know or be able to do upon completion of their classroom experience. Hence, students will be prepared to:

- thrive and lead change in an interconnected world
- understand and engage with dimensions of cultural diversity to find solidarity and achieve common goals
- address today's greatest challenges and make a difference in the world, collaboratively and equitably

Various strategies have been proposed to encourage global learning at the individual and programme levels. At the programme level, students demonstrated a more comprehensive understanding of global learning. They can relate knowledge, skills, and attitudes to the inclusion of more dynamic internationalisation factors and situate global learning within multiple, larger systems. This result aligns with earlier research on the dynamic nature of internationalisation. Thus, students proposed broader and more diverse approaches. This result aligns with previous research on the dynamic nature of internationalisation. As a result of internationalisation, global learning within individual systems and at each level is open, self-organising, and continually changing, shaped by its sensitive connections to other dynamic variables such as purpose, programs, approaches, and projects (Zhou, 2016).

The AAC&U (2014) states that global learning should educate students about the world and the various ways their decisions affect both local and global communities, give them the tools to address urgent global concerns, and teach them to be "attentive to diversity." Based on post-session evaluations, the vast majority of participants believe that global learning helps students understand their place in the world and that they are interested in becoming better global citizens. Furthermore, nearly all students in the global learning classroom believe that engaging with global perspectives helps them understand social issues in other cultures. This allows students to articulate their knowledge, skills, and qualifications to diverse audiences both within and beyond the university, and to engage in structured reflections that connect course experiences to the development of global citizenship. Consequently, this experience can enhance students' learning by making learning objectives intentional, high-impact, and connected to real-world and civic contexts.

4. FINDINGS /UNFOLDING RESPONSIVE LEARNING AND RESPONSIBLE LEARNING EXPERIENCE

This study examined the influence of three Global Learning projects on students' academic performance for three consecutive semesters (20194, 20202 and 20204) between 2019 and 2020. The focus group for this study were students from the Faculty of Law, the Academy of Language Studies, and the Faculty of Health Sciences. The first project, conducted in 2019, involved the Faculty of Law, while the second and third projects, conducted in 2020, involved three faculties: the Academy of Language Studies, the Faculty of Health Sciences, and the Faculty of Law (Figure 2). Online questionnaires were distributed to elicit participants' responses on the impact of the Global Learning programme on learning. The questionnaire was divided into two sections: Section A comprises five questions measured using a Likert scale. At the same time, Section B explores in depth the participants' experiences regarding their Global Learning sessions.

4.1 PARTICIPANTS' FEEDBACK

The term 'global learning' emphasises students' holistic growth by focusing on their internal and external development, aiming to increase their confidence, broaden their perspectives, deepen their knowledge, and encourage critical thinking and intercultural communication (Braskamp, Braskamp & Merril, 2009). Based on this definition, the following five categories were chosen to quantify the effectiveness of the Global Learning Programme conducted in UiTM: i) level of interest, ii) level of confidence, iii) importance of this programme, iv) relevance of the content, and v) contribution of knowledge.

Figure 2 shows that participants in the Global Learning programme not only showed increased interest in learning but also higher confidence. 64.3% of participants strongly agreed that the Global Learning session had increased their interest in learning more, compared with only 33% who agreed. Regarding whether the Global Learning programme contributed to participants' confidence levels, more than half of the participants (60.4%) strongly agreed that it did, 34.1% agreed that their confidence had increased, and 5.4% neither agreed nor disagreed. The findings in this data correlated with Bourne's (2014) theory that global learning encouraged students to develop their self-confidence by asking questions and through discussions.

Data collected from the questionnaire in this study also showed that participants perceived the content of the Global Learning sessions they attended as relevant and important for improving and enhancing their knowledge (See Figure 2). Education at universities should focus on the development of knowledge and skills; therefore, the content of any Global Learning programmes should be current, relevant, and flexible to global changes (Marsella, 2007). The participants' responses in this study regarding the importance of this programme, the relevance of the content, and the knowledge contribution concurred with Marsella's (2007) viewpoint. The data indicated that participants strongly agreed that what they learned in the Global Learning session was important (68.7%). 66.5% stated that the content of this programme is important in understanding their course, and that by participating in this Global Learning programme, their knowledge and understanding of the topics in their courses have increased substantially (69.8%). It is interesting to note that none of the participants disagreed with or strongly disagreed with any of the statements in the questionnaire.

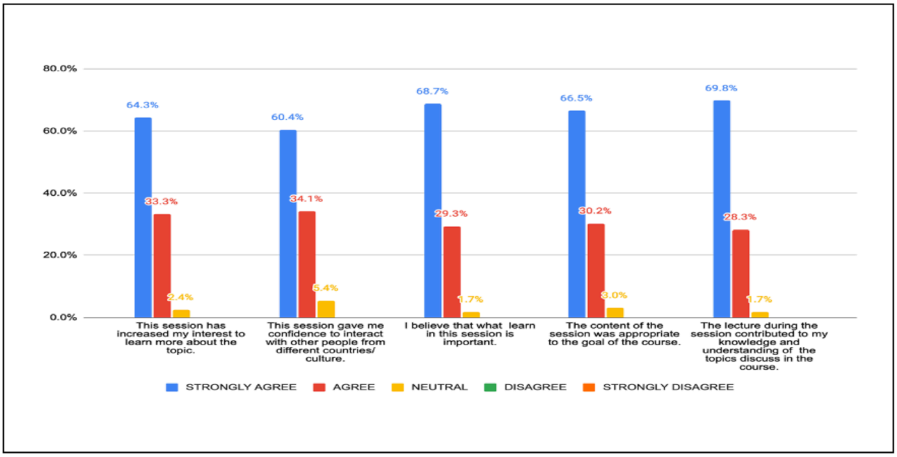

Figure 2. Participants' feedback on Global Learning Experience

An in-depth understanding of participants' experiences with the benefits of the Global Learning programme was also obtained from the questionnaire. The following questions were asked:

i) How do you feel after listening to the session?
ii) What have you learned from the talk today?
iii) Would you like to have more of these sessions? Any suggestions for improvement?

The respondents' feedback revealed that they not only felt inspired, confident, motivated, and excited after participating in the Global Learning sessions, but also reported that the session content helped enhance their knowledge. These are illustrated below:

Feel inspired:
- *I feel more inspired to see the culture and workplace of the other countries*
- *I am interested in learning more and deeper about business*
- *It makes me interested and motivated to explore and learn more things about business overseas*

Improve confidence:
- *Yes. This is an interesting sharing session that could increase students' confidence and help them gain more knowledge. I learned that we must be confident in ourselves and always remember our reason for starting a business when we feel like giving up.*
- *I feel more confident to be an entrepreneur*

Enhance motivation:
I feel more motivated to be a successful woman
I feel very motivated to continue to study further
I felt more motivated. I learned new things and want to improve myself better after listening to this talk
I feel motivated to relate my current work scope to the environmental issue.

Arouse excitement:
Awesome that we can share ideas and knowledge with Dr Beatriz
Excited because I get new knowledge from this lecture

Enhance knowledge:

I gained new knowledge and see the operation management from a new perspective

I feel enlightened. All the knowledge given to me was something new, hence it gives me a new perspective on how the law in Indonesia regulates the environment

I feel lucky to attend this session because it helps me to gain more knowledge about this topic

My feeling was so happy because I could learn more about Japanese culture

4.2 GLOBAL LEARNING PROGRAMME AND PARTICIPANTS' ACADEMIC PERFORMANCE

Does the Global Learning programme prepare students for the future? Does it promote higher thinking skills and improve their academic performances? In this study, students' academic performance, measured by Grade Point Average (GPA) and Cumulative Grade Point Average (CGPA), was used to assess the effectiveness of the Global Learning programme.

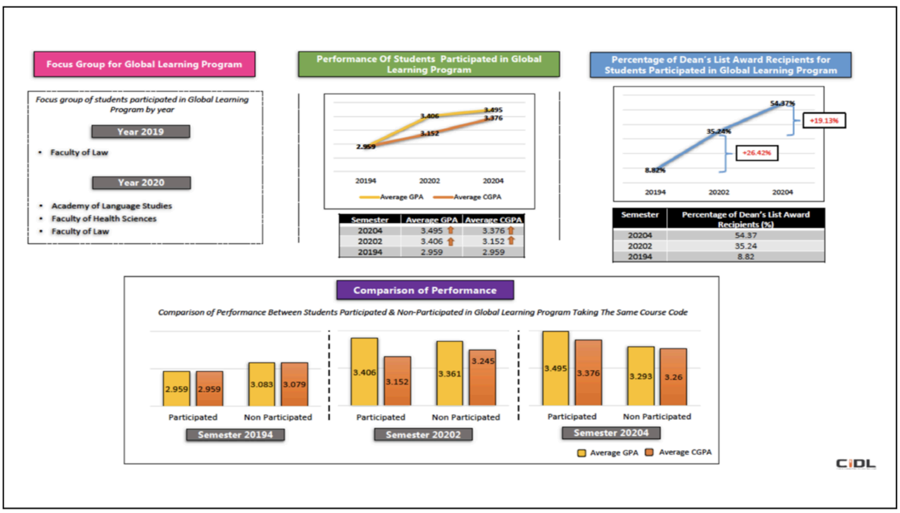

Figure 3. The impact of Global Learning on students' academic performance

Figure 3 illustrates the impact the Global Learning programme had on students' academic performance. Students who participated in the Global Learning programme showed significant improvements in their GPA and CGPA across the three projects. The first project conducted in semester 20194 showed an increase in students' GPA scores (M=2.959 to M=3.406). In contrast, students who participated in the second project conducted in semester 20202 recorded an even higher GPA score (M=3.495). Similarly, students' CGPA scores improved, with all students who took part in this programme increasing their CGPA from 2.959 to 3.152 in semester 20202 and to 3.376 in semester 20204.

Students who participated in the Global Learning programme in this study were also more likely to be conferred the Dean's List Award (Figure 3). 8.82% of Global Learning participants were presented with the Dean's List Award in semester 20194, 35.42% in semester 20202 and a further increment of 19.13% in semester 20204.

A comparison of students' academic performance between those participating in the Global Learning programme and those who did not was conducted (Figure 4). In the first project (semester 20194), the results showed that Global Learning participants did not achieve higher academic performance than their counterparts. The GPA and CGPA mean scores of students engaged in the Global Learning programme were lower (M=2.595) compared with the GPA mean score of 3.083 and the CGPA mean score of 3.079 for non-participants. The Global Learning group performed better in the second project (semester 20202), with slight improvements in the GPA (M=3.406) and CGPA (M=3.361) scores compared with the non-participant group. In contrast, the mean GPA and CGPA for the non-participant group were lower at 3.152 and 3.245, respectively. The same conclusion can be drawn for the third project (semester 20204), with the Global learning group outperforming the non-participant group in both their GPA and CGPA scores.

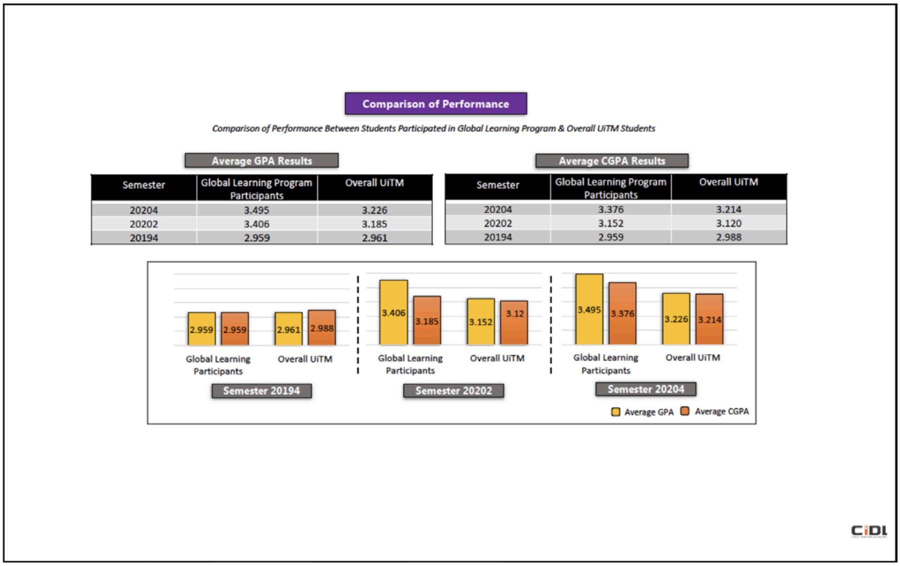

Figure 4. Comparison of performance between students who participated in the Global Learning programme and overall UiTM students

A comparison of academic performance between students enrolled in the Global Learning programme and all students at UiTM was conducted (Figure 4). The first project (semester 20194) displayed mixed results. The GPA score (M=2.959) for participants of the Global Learning programme was similar to that of the overall UiTM students' group. In contrast, the overall UiTM student group did slightly better (M=2.988) than the Global Learning participants (M=2.961) in CGPA. For the second and third projects (semesters 20202 and 20204), the results favoured students who participated in the Global Learning programme. The Global Learning participants had higher mean GPAs and CGPAs than the overall UiTM student population.

In summary, the findings in this study align with Bourn's (2014) theory of global learning, which treats global learning as a process. Students are exposed to different approaches and ways of understanding the world, thereby enhancing their attitudes, motivation, knowledge, and communication skills. The Global Learning programme at UiTM reflects this, as it not only broadens students' global vision but also enhances their knowledge, encourages critical thinking, and improves communication.

5. CONCLUSIONS

Global learning fosters a broader understanding and global consciousness across fields, enabling students to learn, interrogate, and reflect on the world without physically crossing borders. It is about moving minds, not bodies, through virtual mobility, as lectures and seminars are delivered via various synchronous online platforms. As a high-impact learning experience, Global Learning ensures that students actively engage in real-world applications of knowledge and practice responsive learning.

6. ACKNOWLEDGEMENTS

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8. AUTHOR'S CONTRIBUTION

The development and execution of this research were a collaborative effort among the listed authors. Oswald Timothy Edward served as the primary lead, responsible for the study's initial conceptualisation and the preparation of the original draft. The methodological framework was developed jointly by Oswald Timothy Edward and Siti Hafsyah Idris, and Oswald Timothy Edward and Julina Munchar conducted the formal analysis. Furthermore, the final manuscript underwent extensive review and editing by Oswald Timothy Edward, Siti Hafsyah Idris, and Julina Munchar to ensure intellectual rigour and clarity. Ultimately, all authors have reviewed and approved the final version of the manuscript for publication.

9. CONFLICTS OF INTEREST DECLARATION

The authors declare that there are no known financial or personal relationships that could have appeared to influence the work reported in this paper. Although the study was developed within the context of institutional academic initiatives, including Global Learning activities at Universiti Teknologi MARA (UiTM), Malaysia, these initiatives did not involve any financial support, commercial interests, or contractual obligations related to the research outcomes. The design of the study, the collection, analysis, and interpretation of data, the writing of the manuscript, and the decision to submit the manuscript for publication were conducted independently by the authors.

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Transforming Learning: Incorporate Virtual Exhibitions into Teaching

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Abstract: *Advancements in digital technologies present exciting opportunities for art curators and educators to develop engaging art exhibition activities. Digitalisation effectively addresses challenges such as limited resources, funding, and technical support that often confront not only arts professionals but also, more critically, educators in higher education. These challenges are particularly significant for archiving, curating, and exhibiting projects centred on popular culture, especially those related to the entertainment industry. This paper posits that art educators can leverage digital technologies to train future curators and art exhibition specialists by incorporating virtual exhibitions into their syllabi and practices. This approach unlocks new opportunities for exploration within the field and enhances students' understanding of exhibitions and curatorship through digital technologies. This paper aims to share our experiences from a semester-long exhibition and curatorship course offered as part of the Arts Management program at Universiti Teknologi MARA, Puncak Perdana Campus. The project, titled 'Let's Digital,' is founded on three key pillars: robust support for technology in the archiving of digital data, curating, and exhibiting; the flexibility to cultivate new concepts and technologies in diverse environments; and the fostering of technological proficiency to equip students with essential lifelong learning skills for future workforce success. This technology-integrated, creative educational approach to preserving and curating exhibitions aims to provide students with flexible learning* *opportunities. Through these processes and by embedding technology, they acquire knowledge of Malaysian popular culture, developing theoretical and practical digital skills that enhance their personal development and deepen their understanding of exhibitions and curatorial practices in the digital age.*

Keywords: *Digitalisation, learning experience, technological integration, virtual exhibition.*

1. INTRODUCTION

Curatorial and exhibition practices in the arts have long been valued for their traditional approaches, which allow artworks to be experienced in physical spaces. However, in today's digital age, our interactions and communications have transformed, affecting many aspects of our lives. This evolution reshapes social practices and influences how we engage with art. The emphasis here is on incorporating digital media technologies into art exhibition education and improving curatorial practices. Additionally, engaging with popular culture and its artefacts fosters collective public memory and highlights facets of our cultural heritage that are often overlooked. This educational and technological shift invites us to explore and celebrate local and contemporary artworks, enriching our understanding of societal and cultural identities in more engaging and meaningful ways. While Malaysia's popular culture is undeniably vibrant, the documentation surrounding it remains limited.

According to Altinay and Jokić (2020), the growth of popular culture collections in mainstream institutions, alongside the emergence of specialised repositories, has challenged traditional academic standards and value hierarchies. This evolution has facilitated access to a diverse array of alternative perspectives on history and culture. Waller and Waller (2021) observe that numerous scholars contend that the pop music and songs we enjoyed during our youth can be regarded as a form of "heritage." As we age, the music from our formative years acquires sociocultural and historical significance, highlighting its value as heritage. Popular culture, including pop songs and music, serves not only as entertainment but also plays a vital role in shaping social and cultural history. To fully understand this phenomenon, it is essential to consider related artefacts such as photographs, programs, tickets, posters, costumes, and instruments. These elements provide critical insights that enhance our understanding of the past and can be invaluable in the learning process. Waller and Waller also emphasise the growing body of research examining the role of popular culture and music in cultural heritage processes. According to them, this effort aligns with a broader trend towards revitalising nostalgia-driven cultural expressions from the twentieth century. The complex processes of "heritagisation," "museumification," and "ratification" involve the collection, archiving, commercialisation, conservation, digitisation, remembrance, and exhibition of various tangible and intangible cultural assets.

Archiving has long been a fundamental resource for curators and researchers, facilitating effective information curation across various fields. Emphasising the significance of documenting and preserving all information is crucial for ensuring transparency and the longevity of the collection and reasoning processes. As Cameron (2021) points out, the challenge of physical archiving is the accumulation of research data without proper access, which can lead to stagnant archives. Nevertheless, fortunately, the advent of digital media technologies and the World Wide Web has significantly transformed and continues to shape the practices of information and data archiving. This digital revolution has seemingly fostered a "widespread storage obsession" and a "fetishisation of data." The challenges outlined are considerable for education in archiving, curatorial practices, and art exhibitions focused on popular culture, particularly within the entertainment industry in countries like Malaysia. Today, various free digital tools and applications, such as Canva, Numbers and Artsteps, can effectively document, archive, and curate virtual exhibitions as alternatives to traditional formats. This paper proposes that art educators can seamlessly incorporate digitalisation into their curricula, syllabi, and practices to prepare future curators and art exhibition specialists by incorporating virtual exhibitions. This approach opens new avenues for exploration within the field and enhances our understanding of exhibitions and curatorship through the application of digital technologies.

2. ARCHIVING THE ARTS AND CULTURE

The field of archiving has traditionally been considered the primary resource for curators to curate exhibitions properly; this circumstance allows curators to draw on a wide range of fields. Researchers believe that we must document and preserve all information to ensure the transparency and permanence of the gathering and reasoning process. Nevertheless, according to Cameron (2021), accumulating research data without appropriate access may result in a stagnant archive, with “billions of files resting like sediment in the cloud, on external drives.” Luckily, new technologies, such as the printing press, lithography, photography, film, computers, and the World Wide Web, have historically influenced and continue to affect archiving practices since their debut. Digital media appears to have precipitated a “widespread storage obsession” and a “fetishisation of data.”

Lawther, in an interview with Goskar (2021), asserts that, despite the impossibility of possessing comprehensive knowledge of every object or collection, it is crucial to document our existing knowledge to prevent its loss or forgetting. As stated by Oliver (1965), knowledge manifests in two forms: (1) “active knowledge,” which resides in the minds of living individuals, readily accessible for immediate action, and (2) “passive (or potential) knowledge,” which is contained within the extensive repository of documents that chronicle the experiences, observations, thoughts, and discoveries of others, primarily from the past. Oliver also highlighted that human progress has paralleled and, seemingly, depended on the growth and availability of this great reservoir of “passive knowledge.”

Pop culture has become an essential component of popular media, disseminating messages, promoting products, and shaping individuals’ perspectives (Chowdhury, 2023). It has also been employed to influence political decisions and affect public opinion. Pop culture has been used to drive social change, raise awareness of critical issues, and foster a sense of unity and belonging across diverse groups. In Malaysia’s popular culture, the lives of iconic figures such as Tan Sri P. Ramlee, Puan Sri Saloma, Sudirman Haji Arshad, Datuk Sharifah Aini, and Dato’ Siti Nurhaliza Taruddin are frequently discussed, and details of their lives are often made public. Stories and news about them have been shared for popular reasons, but remain unknown to the younger generation.

In recent years, the archiving environment for Malaysia’s art and culture has undergone significant changes. Archiving is conducted not just by Arkib Negara Malaysia but also by independent archives and individuals who recognise the long-term significance of archiving, like Penang House of Music, MY Art Memory Project (MAMP), Arts Education Archive Malaysia (AEAM), Malaysia Design Archive, and Malaysian Art Archive & Research Support

(MARS) (Lee, 2021). The rise of the internet and advanced technologies has transformed traditional archiving into digital formats, significantly increasing its importance, particularly in preserving primary materials from the past.

The world is unequivocally entering a new epoch—the revolution of online education with innovative instructional tools. Pervez et al. (2018) emphasised the need for teachers, educators, and institutions to broaden the use of educational technology and to develop a comprehensive understanding of pedagogical issues. Education will expand significantly, particularly through the integration of technology and innovative tools. According to Tikader (2023), in the swiftly advancing digital era, innovative technologies are crucial in reshaping higher education. This is because fast-evolving technologies not only facilitate students' learning but also equip them with the digital skills necessary to compete in the contemporary world.

As previously stated, new tools are emerging, and as educators, we can readily utilise free and innovative apps for educational purposes. In this study, the educator will use Numbers and Artsteps, free and user-friendly applications, as teaching tools to enhance the teaching and learning process. Artsteps is an online tool that enables designers to create exhibitions, events, and brand storytelling concepts, while Numbers is an Apple-developed application that brings our data to life. Numbers makes it possible to create beautiful spreadsheets and designs, and comes included with most Apple devices. Students and educators may use the Apple Pencil on their iPad to add useful diagrams and colourful illustrations. Moreover, with real-time collaboration, they can work together, whether on a Mac, iPad, iPhone, or PC. We might regard these applications as ecologically conscious activities and materials that promote sustainability and foster innovation. Let's Digital also aligns with the significance of the Sustainable Development Goals (SDG). The SDGs provide a robust, universal vocabulary and an opportunity to address collective challenges, becoming part of a global movement towards sustainability that offers a framework for innovation, collaboration, and the exchange of solutions and best practices among educators and learners. In this project, the researchers incorporated the significance of Sustainable Development Goals (SDGs) into two specific goals:

- Goal 4 - focuses on quality education. It sets a goal for students to attain sufficient levels of education and acquire the necessary skills for productivity and employment.

- Goal 17 - focuses on fostering partnerships. It underscores the importance of access to science and technology, particularly internet-based information and communication technologies. These talents assist individuals in their personal and professional lives and enable them to participate in a global society.

Archival preservation aims to extend the usable life of research information for future use. Regrettably, public archives related to popular culture in Malaysia were not properly documented and archived. As Lawther (in Goskar, 2021) highlights, each undocumented or poorly documented object is a missed opportunity for the museum to do what it is celebrated for: engaging people, connecting people, and sharing stories. She also added that documentation levels are poor in almost every organisation, and it is a shame for all those objects to sit unused in the stores. Unfortunately, research into the impact of digital technology on archives and how this transformed archiving practices in research environments has received less attention. Current research often treats digital archives as static entities that may be searchable and, at best, offer data for download, although this trend is increasingly challenged (Cameron, 2021).

The objectives are as follows:
a. To unleash students' archiving skills through an advanced sustainable platform.
b. To promote self-directed learning in curating among students
c. To provide a platform that facilitates technology fluency and equips students with lifelong learning skills needed to be effective in the workforce.

The study also addressed the research questions as follows:
a. How to unleash students' archiving activity through an advanced sustainable platform?
b. How to promote self-directed learning and curating among students?
c. How to provide a platform that facilitates technology fluency and gives students the lifelong learning skills needed to be effective in the workforce?

In the Museum Management (FFM234) course, a set of activities is designed to highlight the problem and identify a solution to address it. Let's Digital Model will bring out each student's strengths across different skills. Some of the key skills associated with this model include critical thinking, self-awareness, and complex problem-solving. All these skills will work wonders with the help of technology and tools that are now available anytime, anywhere, provided students have an internet connection. For the current semester, the chosen subject of study focuses on the life and legacy of the late Biduanita Negara, Saloma.

3. DEVELOPMENT OF THE LET'S DIGITAL

Let's Digital is a model created under the subject of Exhibition Management (FFM234). It all started during the MCO, when everyone was having difficulty obtaining information and resources for research and exhibits. Let's Digital is an educational initiative that encourages self-directed learning and problem-solving skills among undergraduate students. It achieves this by leveraging Numbers and Artsteps, a free and user-friendly app, as a teaching aid to make the teaching and learning process more efficient and engaging. The objectives of Let's Digital are to provide students with sufficient education and developmental skills to enhance productivity and employment, and to highlight the importance of access to science and technology, including internet-based information and communication technologies. These abilities not only assist individuals in their personal and professional lives but also empower them to engage in a global society.

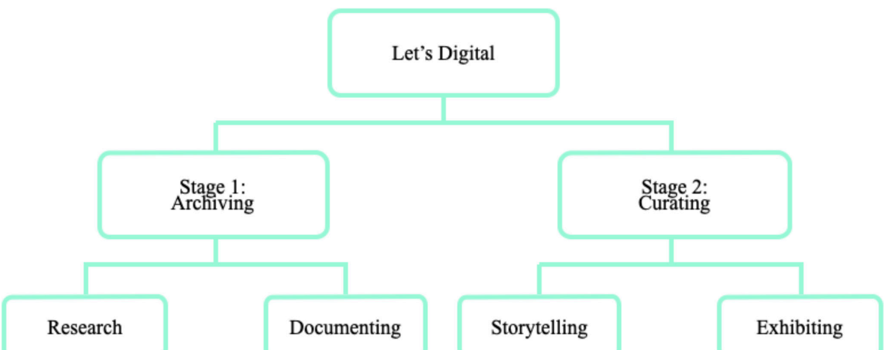


Figure 1. Steps of the methodology used in Let's Digital Model

Stage 1: Archiving

During this phase, students will collectively research and gather information from various resources. Information can originate from a variety of sources, such as social media, blogs, personal experiences, books, journal and magazine articles, expert opinions, newspapers, and websites—and the specific type of information required by students will vary over time; as a result, students must comprehend where to locate types of information. A brainstorming session is employed to generate various elements of a plan, method, solution, or approach, as well as to create checklists. During this step, students will collect information, data, graphics, and statistics to utilise in the design stage. Any format, including printed materials, files, electronic means, or other methods, can capture documented information as a record. This record is significant because it promotes openness and transparency by documenting and demonstrating work activities, making them accessible to the public. It encompasses correspondence, memos, books, plans, maps, drawings, diagrams, pictorial or graphic works, photographs, films, microfilms, sound recordings, videotapes, machine-readable records, and any other documentary materials, irrespective of their physical form or attributes, along with any copies thereof.

Stage 2: Curating

As stated by Nenarokamava (2023), curating is about caring enough to see the potential of an idea and finding the best way of communicating it. For the same objective, students will do the same when curating the exhibition. Carefully curated, planned, and executed exhibitions can educate, captivate, and motivate visitors, while poorly designed exhibitions can leave viewers feeling uninterested or detached. Students will begin curating by experimenting with the elements of storytelling. This is where the students will start questioning, analysing, and organising the information, and acting on the decision made. After meticulous organisation and preparation, students will begin developing the exhibition design concept. The team will begin designing the wall text graphic, incorporating it with the posters, photographs, artefacts, and song lyrics. Visual stimuli, such as labels, signage, auditory elements, and interactive technologies, will help students achieve their objectives. By merging the physical and digital aspects of the display, we harmonise functionality and aesthetics.

3.1 ARCHIVING AND DOCUMENTING PROCESS USING CLOUD-BASED PLATFORM

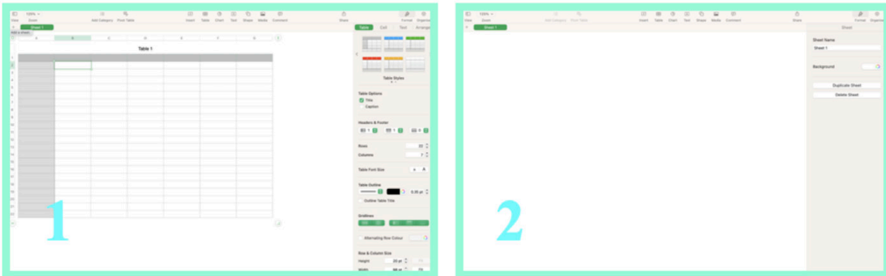
Segregating information into appropriate categories is particularly critical during the archiving procedure. The most effective method is to organise the data by utilising keywords such as (1) personal life story; (2) childhood life; (3) trivia; (4) discography; (5) filmography; (6) cover album; (7) film poster; and (8) accomplishment. Designated groups will handle each keyword to start the research and archiving process.

Figure 2. Simple archiving framework

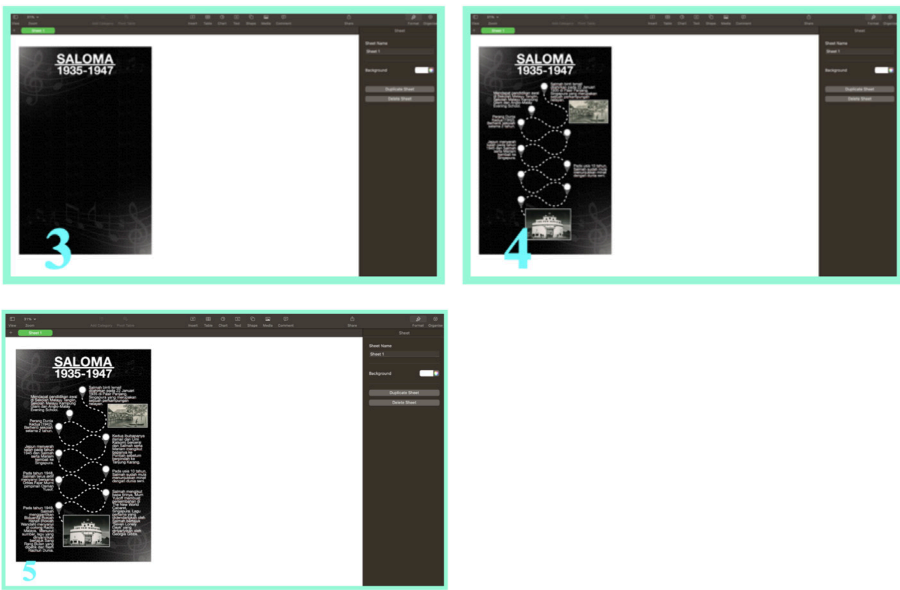
With advances in technology and the rise of the internet and digital documents, digital archiving has become a necessity. All data collected will be stored in a cloud-based archive. The advantages of cloud-based archiving are accessibility from anywhere, scalability, reduced storage costs, and automatic updates.

3.2 DESIGNING PROCESS USING NUMBERS

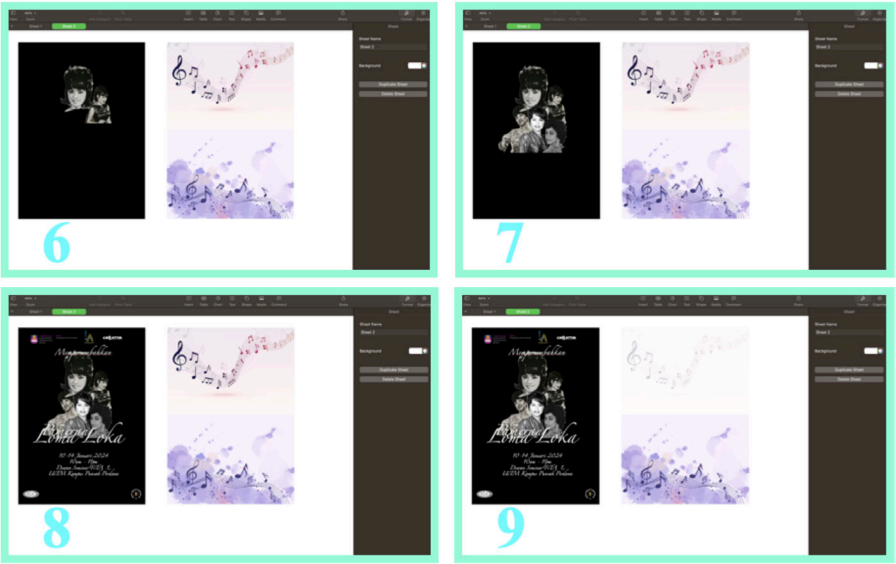
Numbers is a user-friendly platform designed to function like Microsoft Excel, but with creative manipulation of its impressive tables and images. It makes it possible to create beautiful spreadsheets and exhibition wall text. Numbers starts with a blank canvas instead of an endless grid like Microsoft Excel. Users will have the freedom to move everything around the canvas and organise data however they choose. An additional amazing feature is that anyone with access to the file can edit it.



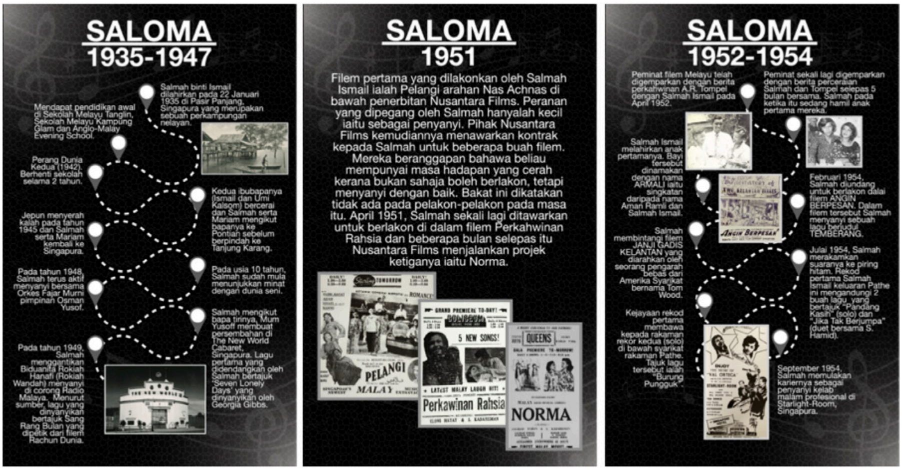
Pictures 1 & 2 - Numbers will start a table, and the first step is to delete it to get a blank canvas



Pictures 3, 4, and 5 - A step-by-step guide for designing the wall text using the Numbers App by creating the watermark, base-shape and colours.



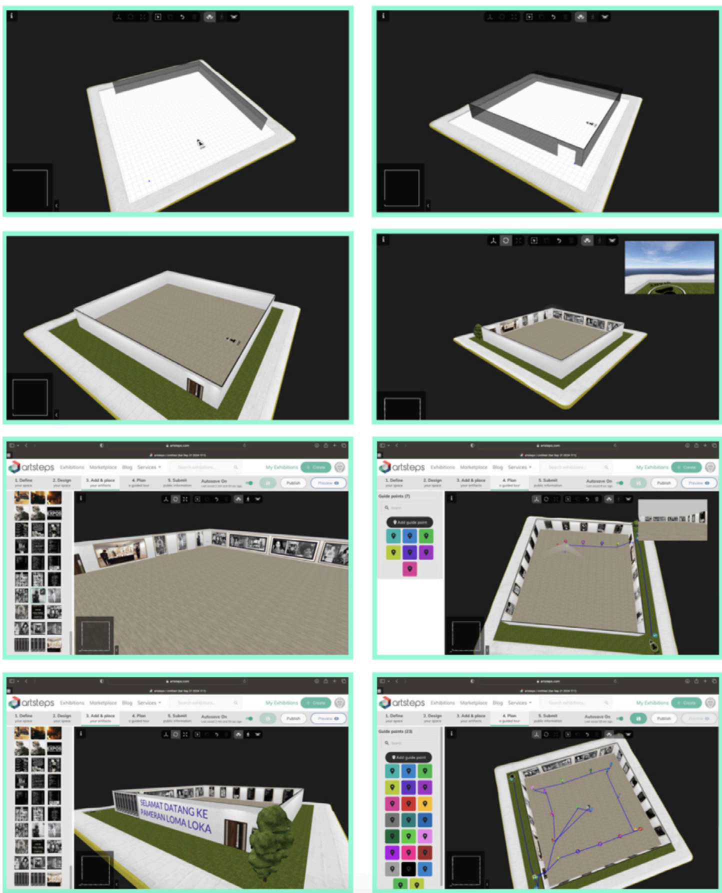
Pictures 6, 7, 8, and 9 - A step-by-step designing exhibition poster using Numbers App.

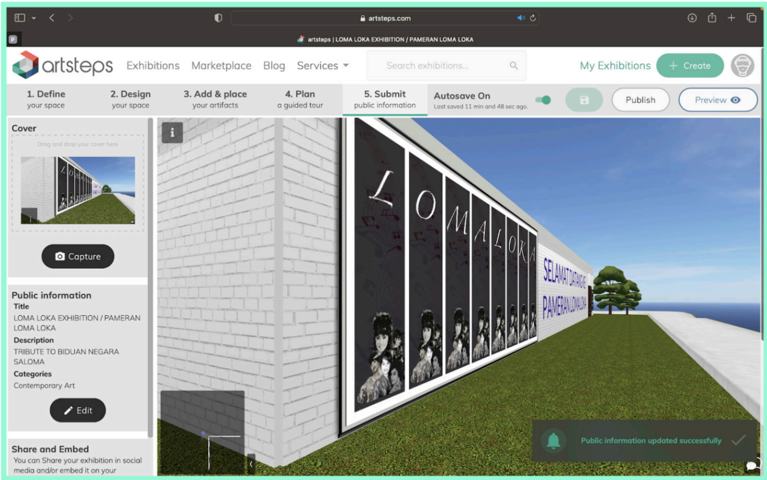


Some of the design of the wall text for the virtual exhibition

3.3 DEVELOPMENT OF VIRTUAL EXHIBITION USING ARTSTEPS

Artsteps is an intuitive tool enabling users to design and personalise their virtual spaces and homes. Users can augment these areas by incorporating web links, text, audio, and video information (Fokides & Zampouli, 2017). The Artsteps platform is accessible at http://www.artsteps.com/. The platform facilitates various virtual learning environments, including (i) the exploration of art within 3-D virtual galleries; (ii) the creation of 3-D virtual exhibitions; and (iii) the integration of digital creations on blogs or websites (Cruz & Torres, 2023).





For a preview of the learning outcome, click the link below.
https://www.artsteps.com/view/66ee8b6a4894ae2ff8a96e3e

4. OUTCOME OF THE LET'S DIGITAL VIRTUAL EXHIBITION

The collected data from the participating students clearly showed that the Let's Digital expanded their perspectives on archiving and curating. The participants' responses to the Let's Digital activity were overwhelmingly positive and diverse, emphasising several features that made it remarkable. This feedback not only affirmed Let's Digital's effectiveness as an educational aid but also highlighted its significance as a facilitator of self-directed learning. A set of five (5) point questions is distributed to 87 respondents rated on a five-point Likert rating scale.

	Total of Responses (n=87)				
	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Do you think Let's Digital helps you understand the archiving and curating better?	0	0	2	7	78
Do you think Let's Digital unleashes students' problem-solving skills through an advanced sustainable platform?	0	0	7	9	71
Do you think Let's Digital promotes self-directed learning among students?	0	0	6	6	75
Do you think Let's Digital is impacting your learning process?	0	0	8	7	72
How does the technology used within Let's Digital facilitate students' lifelong learning skills?	0	0	6	7	74

Table 1. Respondents' Feedback

Eighty-seven students unequivocally stated that the Let's Digital activity significantly enhanced their understanding of the exhibition design course. Eighty participants unanimously agreed that Let's Digital improves their problem-solving abilities by utilising an advanced, sustainable platform. In response to an inquiry about self-directed learning, 81 participants indicated substantial agreement that the Let's Digital activity promotes it. They have the autonomy to determine the trajectory, schedule, and venue of their display design efforts. Seventy-nine respondents strongly agreed that the Let's Digital activity significantly impacted their learning experience. Several students observed that participation in Let's Digital activities offers an opportunity to explore diverse platforms related to exhibition design. Throughout the process, students can investigate numerous concepts and ideas. Seventy-four respondents strongly agreed that the technology used in Let's Digital activities enhances their lifelong learning capabilities.

The study clearly answered the research questions asked:

RQ1: How do we unleash students' archiving activity through an advanced sustainable platform?

Answer: Educators have increasingly incorporated digital technology into their curricula to foster student innovation. Student creativity is vital, and educators must foster and develop it to the fullest. Let's Digital fosters students' creative ingenuity by directing them through three unique phases: organising, designing, and creating. In this phase, students use their cognitive, creative, leadership, and decision-making skills to complete their display design effectively.

RQ2: How do we promote self-directed learning and curating among students?

Answer: Self-directed learning (SDL) is a process wherein learners take responsibility for establishing their learning goals, developing strategies, utilising resources, and evaluating their progress. Contemporary educational institutions must provide students with the essential skills and information to adapt to a constantly changing world. Knowledge is proliferating swiftly and significantly across numerous fields. Emerging technologies, including artificial intelligence and the metaverse, are persistently shaping our environment, presenting distinct challenges and opportunities.

RQ3: How do we provide a platform that facilitates technology fluency and gives students the lifelong learning skills needed to be effective in the workforce?

Answer: Lifelong learning has emerged as an essential endeavour in the era of swift technological advancement. Technology has transformed learning modalities, timing, and locations. Human curiosity, the aspiration for personal progress, and rapid professional advancement propel this evolution. Lifelong learning in the digital era is more than just an option; it is a strategic necessity for individuals aiming to thrive in the knowledge-driven economy of the 21st century.

5. CONCLUSION

Archiving, curating, and displaying are topics within the domain of Exhibition Management (FFM234). This subtopic enhances pupils' ability to understand upcoming knowledge. In the absence of appropriate resources and facilities, educators may employ alternate platforms to present new experiments. We can regard Let's Digital as a viable approach to address these issues. In contemporary society, no universal solution exists that applies to all circumstances. Educators must recognise that educational culture is evolving, and that modifications intended to enhance students' lifelong learning competencies are crucial to their success in the professional realm. These abilities enhance individuals' capacity to navigate their personal and professional spheres and empower them to engage effectively with the global community.

Technology is a powerful catalyst for transforming learning by fostering engagement, personalisation, and accessibility. As educational tools and methodologies continue to evolve, educators, institutions, and policymakers must thoughtfully embrace and adapt to these changes. By leveraging technology effectively, the educational landscape can become more inclusive, dynamic, and better able to meet the diverse needs of learners in the 21st century. The integration of technology in education has revolutionised teaching and learning, creating dynamic and engaging environments that enhance the educational experience. This transformation encompasses various technological tools, methodologies, and platforms designed to foster collaboration, accessibility, and personalised learning.

6. SUGGESTIONS

Based on the most crucial factors identified in this study, it is suggested that, when developing a curriculum, educators should consider a wider range of styles and backgrounds. The aim is to ensure that the virtual exhibition benefits the pupils. In addition to all of this, educators need to consider training as a way to maximise their talents and enhance the quality of their future projects.

7. ACKNOWLEDGEMENTS

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8. AUTHOR'S CONTRIBUTION

The authors declare that there is no conflict of interest in this article. Author 1 developed the main project idea, prepared the literature review, and oversaw the overall write-up of the whole article. Author 2 created the virtual scenarios and contributed to the design of the proposed process throughout the project.

9. CONFLICT OF INTEREST DECLARATION

We certify that the article is the authors' and co-authors' original work. 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 IJELHE.

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Gaps in Pre- and Post-Operational Tasks for Open Distance Learning (ODL) Implementation

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Abstract: *This work aims to review the operational tasks involved in implementing Open Distance Learning (ODL). Since the outbreak of Covid-19, ODL has become popular, especially for postgraduate programs. The scope is to review the pre- and post-tasks studied in prior work on ODL implementation. Examples of pre-tasks include applications for accreditation, and post-tasks are students' performance in adopting the ODL approach. A systematic review methodology was used based on 15 articles retrieved from Google Scholar. The string used to perform the literature search is ("Open Distance learning" AND "postgraduate program" OR "computing" OR "Self-Instructional Material" OR "accreditation"). Results show that most prior work focused on post-tasks, such as students' performance and the effectiveness of Self-Instructional Material (SIM). At the same time, a few studies report on the pre-task hurdles of applying accreditation.*

Keywords: *Accreditation, Open Distance Learning (ODL), postgraduate program, Self-Instructional Material (SIM)*

1. INTRODUCTION

The trend towards adopting Open Distance Learning (ODL) in postgraduate coursework seems to be demanding. The COVID-19 pandemic has accelerated the adoption of ODL, and people around the world are becoming accustomed to online learning. In Malaysia, several universities, such as Universiti Teknologi MARA (UiTM), have implemented ODL for postgraduate programs. UTM offered an ODL-based Master of Cybersecurity in 2023, and the first batch already graduated. The ODL learning approach offers flexible pathways suitable for working professionals to continue studying while working (Rashid et al., 2025). ODL offers students to learn at his/her own pace. Advances in technology have made ODL more flexible, making it easier to access educational materials and eliminating barriers related to location and time. This advantage seems beneficial for students: it is cost-effective, allows them to study at their own pace, and eliminates physical barriers. For institutions, it can reduce infrastructure costs and serve more students.

To implement ODL, some processes must be done before and after it is put into place. Quality assurance is an important task that must be completed before implementation. In Malaysia, the Malaysia Qualifications Agency (MQA), under the Ministry of Education, oversees and maintains the quality standards for higher education. Quality assurance is achieved through accreditation. Before implementing ODL, institutions must undertake substantial preparatory work, including curriculum redesign, digital resource development, learning management system configuration, quality assurance documentation, and preparation for accreditation compliance (Marnnoi, 2024). Preparatory work, such as developing comprehensive course materials, recorded lectures, interactive assessments, detailed instructional guides, and extensive documentation portfolios required by program accreditation bodies, is mostly done by coordinators and subject-matter experts, usually lecturers and instructional designers (Rensburger et al., 2021). The program can only be run after getting accredited. After implementation, ongoing tasks include monitoring student engagement, managing virtual laboratories, continuously updating content to keep pace with rapidly evolving technologies, maintaining academic integrity in remote assessments, and preparing periodic accreditation reports. Additionally, faculty must maintain detailed records of student performance data, course delivery modifications, and continuous improvement initiatives to satisfy accreditation review cycles (MQA, 2021).

This documentation burden intensifies, yet no prior work investigates these matters. Hence, this study seeks to address the knowledge gap regarding pre- and post-operational tasks in ODL implementation. The research question developed is: Which pre-operational and post-operational tasks receive insufficient attention during ODL implementation? The hypothesis is that pre-operational tasks, such as accreditation documentation, are more often overlooked than post-operational tasks, such as student performance evaluations, in ODL implementation.

2. RELATED WORKS

ODL came into the picture as early as 1728, when it was known as distance education (DE), and has evolved rapidly with advances in communication technologies (Bozkurt, 2019). While this teaching approach benefits students, it significantly increases the lecturer's workload during the preparation phase (Ali, 2025). Ali (2025) conducted semi-structured interviews with 24 university lecturers involved in blended learning (BL). Blended learning is slightly different from ODL. To the best of our knowledge, no research has investigated lecturers' workload in preparing ODL materials; the closest example is BL. One key difference is that BL requires some on-campus or learning centre attendance, whereas ODL requires no physical attendance (Rashid et al., 2025). Barriers to BL implementation include lecturer resistance, low lecturer self-efficacy, increased lecturer workload, university policy issues, and lack of institutional readiness (Ali, 2025).

The parallels between BL and ODL workload challenges are particularly relevant when considering the documentation and material development requirements both modalities demand. In both contexts, lecturers must transition from traditional teaching methods to creating comprehensive, technology-mediated learning experiences that function effectively with reduced or no face-to-face interaction. This transformation requires not only technical skills in using learning management systems and digital tools but also a pedagogical reimagining of how content is structured, delivered, and assessed. Workload intensification is especially pronounced in ODL, where the complete absence of physical meetings necessitates more thorough and detailed self-instructional materials, anticipatory communication strategies, and robust online assessment mechanisms. Understanding lecturer experiences in BL thus provides valuable insights into the potentially greater challenges faced in pure ODL environments.

ODL research related to students usually is about self-directed learning habits and facing the continuous assessment (Kumari, P., & Asgar, A. (2023), effectiveness of teaching delivery methods (Amir, F.A, & Borhan, R (2021), student perceptions and actual usage of learning material (Bakar. et al, 2022) and students' difficulties in learning via ODL such as technology and internet, student-lecturer interaction, self-management time and difficulty level of assessment (Ghani et al (2022). Beyond these foundational concerns, student-centred ODL research has increasingly explored the psychological and motivational dimensions of distance learning. Studies have examined how factors such as perceived usefulness, technological acceptance, and confirmation of expectations influence overall student satisfaction and continuation intentions in ODL programs (Hashim et al., 2023). The digital divide remains a persistent challenge, with research highlighting disparities in students' access to reliable technology, adequate internet connectivity, and appropriate learning spaces, all of which significantly affect their ability to engage with ODL platforms fully. Furthermore, the absence of immediate face-to-face interaction has been shown to affect not only academic comprehension but also students' sense of belonging and community within their educational programs. Another critical area of investigation involves students' adaptive learning strategies in ODL environments. Researchers have found that successful ODL students typically develop specific competencies, including digital literacy, autonomous learning, and effective time management. However, the transition to these self-regulated learning behaviours does not occur naturally for all students, particularly those from traditional classroom backgrounds who may struggle with the independence and self-discipline required in distance learning contexts. Additionally, assessment anxiety in ODL settings presents unique challenges, as students must navigate unfamiliar examination formats, manage technical uncertainties during online assessments, and cope with limited immediate support when difficulties arise. These multifaceted student-related factors collectively underscore the complexity of ensuring equitable and effective learning experiences in ODL systems.

Self-instructional material (SIM) is a learning material that meets MQA requirements and enables students to learn independently without direct instruction from lecturers (MQA, 2021). In addition to the course lecturer, ODL course material should be developed in collaboration with curriculum developers, instructional designers, graphic designers, and educational technologists (Rensburg, E.V et al., 2020). Research on SIM is related to faculty development programs for the lecturers to prepare the material (Asgar & Satyanarayana, 2021), SIM instructional design (Bakar et al, 2022), Hamidon et al. (2023) and students' engagement through self-study (Tessema, M.A., & Lekthetho, M, 2024). The quality and effectiveness of SIM are crucial determinants of ODL success, as these materials must not only convey content accurately but also motivate learners, provide clear learning pathways, and facilitate meaningful knowledge construction in the absence of traditional classroom dynamics. Furthermore, SIM development requires ongoing evaluation and refinement to ensure alignment with evolving pedagogical approaches and technological capabilities.

Accreditation is a formal recognition conducted by certain agencies. In Malaysia, MQA performs this function for all educational institutions. Ozen (2022) reviewed the importance of quality standards and accreditation for ODL implementation. However, detailed operational processes are not mentioned. Rashid et al. (2025) researched pre-ODL implementation but focused more on students' flexibility elements, such as communication timing, modes, and platforms. A review paper by Zawacki-Richter and Jung (2022) emphasises the importance of internal and external accreditation worldwide.

The implementation of ODL has significantly increased the lecturer workload, primarily through the exponential rise in documentation requirements that are often unrecognised by institutional management. Unlike traditional face-to-face courses, where teaching materials can be relatively informal and supplemented by direct classroom interaction, ODL requires comprehensive, self-contained documentation that anticipates and addresses every possible student query in the absence of immediate instructor presence. Lecturers are required to develop detailed Self-Instructional Materials (SIM) that meet stringent Malaysian Qualifications Agency (MQA) standards, encompassing not only content delivery but also learning objectives, activities, self-assessment exercises, and multimedia integration—a process that can take three to five times longer than preparing conventional lecture notes. Beyond SIM development, lecturers must create extensive course guides, detailed assessment rubrics, video recordings, interactive modules, discussion forum prompts, and multiple versions of assessment materials to ensure academic integrity in online environments. The accreditation process further compounds this burden, requiring meticulous documentation of learning outcomes mapping, quality assurance evidence, student engagement metrics, and continuous improvement records. Additionally, the collaborative nature of ODL material development means lecturers must coordinate with instructional designers, graphic designers, and educational technologists, adding layers of meetings, revisions, and approval processes to their already saturated schedules. This documentation-heavy approach, while necessary for quality ODL delivery, effectively transforms lecturers from educators into content producers and administrative processors, with insufficient recognition, training, or time allocation provided to manage these expanded responsibilities. The irony is that while institutions celebrate their ODL offerings as innovative and student-centred, the actual cost is borne disproportionately by lecturers whose pedagogical expertise and research productivity are increasingly compromised by relentless documentation demands that serve accreditation requirements more than genuine educational enhancement.

Figure.1 illustrates the theoretical framework of this study. The dependent variable is ODL implementation, and the independent variables are pre-operational and post-operational. The pre-operational task might be an accreditation process, such as SIM preparation and evaluation. The post-operational task might involve student-related processes, such as monitoring student engagement and conducting continuous assessment.

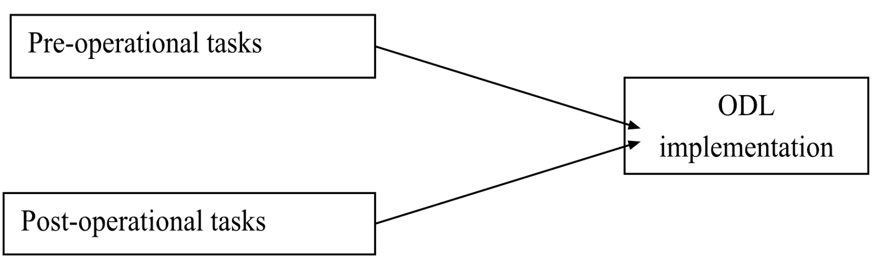

Figure 1. Theoretical Framework

3. METHODOLOGY

This work used a systematic review methodology to search for related articles (Shuhida, 2022). The Google Scholar database has been used to search for related articles. The string used to perform the literature search is ("Open Distance learning" AND "postgraduate program" OR "computing" OR "Self-Instructional Material" OR "accreditation"). The selection criteria are based on ODL implementation, focusing on pre- and post-operations, student-related, lecturer-related, SIM-related, and accreditation-related. The term "related" is used to indicate, in general, the research done by the selected articles. 15 articles published in English between 2021 and 2025 were selected. The review aims to provide an overview of patterns in pre- and post-operational tasks related to ODL implementation, focusing on elements related to students, lecturers, SIM, and the accreditation process. By employing a systematic literature review, it was possible to discern trends and patterns and to evaluate the existing literature on ODL implementation issues.

4. RESULTS

Table 1 shows the results of the review. The column table is divided into Pre-post ODL, Student-related, Lecturer-related, SIM-related, and Accreditation-related. Based on the table, several distinct patterns emerge across 15 selected articles. It shows that post-ODL has 13 articles and only two research articles on pre-operation tasks for ODL implementation. A predominant emphasis on 'student-related' has been the majority, with 10 out of 15 studies addressing this issue. 'Lecturer-related' aspects receive moderate attention, appearing in 6 studies, including works by Rensburg et al. (2021), Asgar & Satyanarayana (2021), and Ali (2024). This indicates recognition of educators' roles in ODL success, though less extensively explored than student factors. 'Self-Instructional Material (SIM)' concerns are addressed in 6 studies, suggesting growing awareness in SIM development and quality. 'Accreditation-related' research remains notably underexplored, with only 3 studies (Rensburg et al. (2021), Zawacki-Ritcher & Jungs (2022), and Ozen, E.) (2022) addressing quality assurance and institutional recognition. This gap is particularly significant given the importance of accreditation for ODL legitimacy and student outcomes. The table reveals that while student experiences dominate current research, critical areas such as accreditation, comprehensive lecturer support, and integrated approaches that address multiple dimensions simultaneously remain underdeveloped, pointing to important directions for future ODL research.

Bil.	Authors, Year	Pre or Post ODL	Student's related	Lecturer's related	SIMs related	Accreditation's related
1.	Rensburg et al. (2021).	Post	▯	✔	▯	✔
2.	Asgar & Satyanarayana (2021)	Post	▯	✔	✔	▯
3.	Amir, F.A, & Borhan, R (2021)	Post	✔	▯	▯	▯
4.	Ghani et al (2022)	Post	✔	▯	▯	▯
5.	Abdullah, Z., & Said, M.N.H (2022)	Post	✔	✔	▯	▯
6.	Bakar et al. (2022).	Post	✔	▯	✔	▯
7.	Zawacki-Ritcher, I.Jungs, 2022	Post	▯	▯	▯	✔
8.	Abdullah, Z., & Said, M.N.H (2022)	Post	✔	✔	✔	▯
9.	Kumari, P., & Asgar, A. (2023).	Post	✔	▯	▯	▯
10.	Hamidon, M.L. Abdullah, Y. Yusoff (2023)	Post	✔	✔	✔	▯
11.	Sharma, K., & Ravi, Indu. (2023)	Post	✔	▯	✔	▯
12	Tessema, M.A. & Lekhetho, M. (2024)	Post	✔	▯	✔	▯
13.	Ali, R (2024)	Post	▯	✔	▯	▯
14	Rashid,K., Kamar, I.F.M., Zahari, N.F, Rahmat, A. & Masri, M.H.M. (2025)	Pre	✔	▯	▯	▯
15.	Ozen, E. (2022)	Pre	▯	▯	▯	✔

Table 1. Gaps in ODL implementation (2021-2025)

5. CONCLUSION

This study reveals significant patterns and gaps in ODL. This work has shown that pre- and post-operational tasks are important, but pre-operational tasks have not been explored much. The analysis demonstrates a clear temporal and thematic imbalance in the current literature. Temporally, there is an overwhelming focus on post-implementation studies (13 articles) compared to pre-operational research (2 articles), suggesting that the field has been predominantly reactive rather than proactive in addressing ODL challenges. Thematically, the review shows a pronounced focus on student-related factors, which appear in two-thirds of the studies examined (10 out of 15). While this emphasis acknowledges the centrality of learner experiences in ODL success, it comes at the expense of other equally critical dimensions. Lecturer-related aspects and Self-Instructional Materials (SIM) development receive moderate attention, each appearing in 6 studies, indicating emerging but still insufficient scholarly engagement with pedagogical delivery and content quality issues. Most concerning is the marked underrepresentation of accreditation-related research, with only 3 studies addressing quality assurance and institutional recognition frameworks. This gap is particularly problematic given that accreditation serves as a cornerstone for ODL legitimacy, stakeholder confidence, and ultimately, student outcomes in an increasingly competitive educational landscape.

6. SUGGESTION

The review findings suggest that current ODL research remains fragmented, lacking integrated approaches that address multiple dimensions simultaneously. To advance the field, future research must adopt more holistic frameworks that balance perspectives on student, lecturer, material, and institutional quality. Additionally, there is an urgent need for pre-implementation studies that can inform strategic planning rather than merely evaluate outcomes. Addressing these gaps will be essential for developing robust, sustainable, and quality-assured ODL systems that meet the evolving demands of 21st-century education.

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9. AUTHOR'S CONTRIBUTION

The authors declare no conflicts of interest regarding this article. Siti Arpah Ahmad was responsible for the principal components of this review paper, including article selection, drafting the introduction, and overall manuscript supervision. Zarina Zainol contributed to the research methodology section and analysed results.

10. CONFLICT OF INTEREST DECLARATION

We certify that the article is the authors' and co-authors' original work. 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 IJELHE.

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Advancing Teaching Excellence in the Era of Education 5.0: Learner-Driven Pedagogy, Technology Integration and Research-Informed Practice

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Abstract: *The rapid advancement of Industry 4.0 technologies has reshaped higher education, requiring teaching excellence to be redefined in the era of Education 5.0. This paper explores how Malaysian higher education can advance teaching excellence by embedding learner-centred pedagogy within technology-enhanced learning environments. It analyses how artificial intelligence (AI), big data, gamification and digital platforms enable interactive, personalised, and inclusive learning, while also addressing challenges such as the digital divide, cybersecurity and faculty readiness. The paper further highlights the importance of collaborative and interdisciplinary approaches, supported by academic research and policy frameworks such as the Higher Education Plan 2025–2035 and Education 5.0@UiTM. The findings argue that technology in learning is not merely a tool for content delivery but a transformative enabler of engagement, employability and ethical resilience. By integrating pedagogy, technology and research, higher education institutions can build adaptive ecosystems that prepare graduates for dynamic and uncertain futures.*

Keywords: *AI Education, Cybersecurity, Education 5.0, Gamification, Learner-Centred Pedagogy*

1. INTRODUCTION

The global landscape of higher education is rapidly changing under the dual influence of Industry 4.0 and Education 5.0. Industry 4.0, characterised by artificial intelligence (AI), big data, robotics and the Internet of Things (IoT), has redefined how societies work and interact. Education, as a critical driver of socio-economic progress, is essential to adapting to this technological revolution by producing graduates who are not only knowledgeable but also adaptable, creative, and digitally literate (Schwab, 2017). Concurrently, Education 5.0 has emerged as a paradigm that emphasises human-centric, values-driven learning where technology serves as a facilitator rather than a substitute for human engagement (UiTM, 2019). Building on UiTM's Education 5.0 framework, which highlights five key pillars: Coherent and Relevant Curriculum, Innovative Delivery and Assessment, Meaningful Learning Experience, Transformative Learning Environment, and Inspiring Educators, teaching excellence in Malaysian higher education can be aligned with these humanised, values-based educational principles.

For Malaysia, this transformation is particularly significant. The Ministry of Higher Education (MOHE) has outlined ambitious reforms in the draft Higher Education Plan 2025–2035, which prioritises graduate employability, curriculum modernisation and digitalisation of learning environments. Similarly, the 13th Malaysia Plan allocates substantial resources for educational transformation, signalling the centrality of higher education in national development (Economic Planning Unit, 2025). In this context, teaching excellence can no longer be defined solely by content delivery or traditional performance indicators. Instead, it must be reimagined as a holistic practice encompassing learner-centred pedagogy, technology-enhanced learning, interdisciplinary collaboration, and research-informed teaching.

This paper situates itself at the intersection of policy, pedagogy and technology. It advances the argument that teaching excellence in the era of Education 5.0 requires universities and academics to (1) adopt learner-driven pedagogical approaches, (2) leverage technology for interactive and equitable learning experiences, (3) promote collaborative and interdisciplinary teaching, and (4) strengthen the role of research in enhancing teaching quality. Each of these dimensions will be explored in detail, with specific emphasis on the Malaysian higher education context. The paper also discusses the challenges of implementation, particularly the digital divide, uneven institutional capacity and the need for sustained professional development among educators.

By reframing higher education through these lenses, Malaysia can position itself not merely as a respondent to global trends but as a leader in shaping adaptive, inclusive and future-ready education ecosystems. The sections that follow examine how these priorities can be realised and integrated within higher education institutions, drawing on both national policy frameworks and international best practices.

2. LEARNER-CENTRED PEDAGOGY FOR TEACHING EXCELLENCE

The pursuit of teaching excellence in the era of Education 5.0 begins with a fundamental reorientation from teacher-centred to learner-centred pedagogy. Traditional models of higher education, often characterised by lecture-heavy content delivery and examination-driven assessment, are increasingly inadequate in preparing graduates for complex and rapidly evolving labour markets. Learner-centred pedagogy, by contrast, prioritises active engagement, autonomy and co-construction of knowledge, ensuring that learners play an active role in shaping their educational experiences (Weimer, 2013).

2.1 RATIONALE FOR LEARNER-CENTRED PEDAGOGY

Learner-driven approaches are supported by evidence that students who actively engage with content, collaborate with peers, and apply their learning in authentic contexts achieve deeper understanding and longer-term retention (Prince, 2004). In Malaysia, this emphasis aligns with national policy objectives, such as the Higher Education Plan 2025–2035, which identifies graduate employability, critical thinking, and innovation as central outcomes (MOHE, 2025). Aligning pedagogy with these outcomes requires a redesign of curricula to emphasise competencies such as problem-solving, digital literacy, ethical reasoning, and teamwork. UiTM's educator acceptance study

(Mohd Salleh et al., 2020) indicates that lecturers across 26 faculties and 35 campuses show strong understanding and positive acceptance of the Education 5.0@UiTM framework, reflecting institutional readiness for learner-driven and personalised education.

2.2 PRINCIPLES OF LEARNER-CENTRED PEDAGOGY

Key principles of learner-centred pedagogy include:

- Active learning: Activities such as case studies, simulations, flipped classrooms, and problem-based learning empower students to construct knowledge actively.
- Personalised pathways: Flexible curricula that allow learners to choose modules, stack micro-credentials or integrate experiential learning promote ownership of the learning process.
- Authentic assessment: Assessment methods that mirror real-world tasks, such as portfolios, project reports, design prototypes and collaborative challenges, may enhance the transferability of skills.
- Reflective practice: Encouraging students to reflect on their learning processes strengthens metacognition and self-directed learning capacities.

These principles resonate with Education 5.0's call to "liberate learning from the constraints of academic weeks and places," promoting seamless, self-directed and meaningful learning experiences (UiTM, 2019).

2.3 PEDAGOGICAL MODELS AND PRACTICES IN MALAYSIA

Several Malaysian universities have begun experimenting with learner-centred pedagogies. For instance, Universiti Teknologi MARA (UiTM) has pioneered Education 5.0@UiTM, an initiative that blends values-driven education with learner empowerment, emphasising the cultivation of both knowledge and character (UiTM, 2019). Similarly, Universiti Malaya has implemented interdisciplinary capstone projects that place students in real-world problem-solving contexts with industry partners (UM, 2022). These initiatives signal a growing recognition that teaching excellence must be redefined in terms of the learner's experience and outcomes.

2.4 CHALLENGES AND OPPORTUNITIES

While the rationale for learner-centred pedagogy is compelling, its implementation faces challenges. Academics trained in traditional methods may lack familiarity with active learning strategies, while students accustomed to rote learning may initially resist the shift toward autonomy. Institutional barriers, such as rigid curriculum structures and performance metrics tied to examination results, further impede transformation. Nonetheless, opportunities abound: national policies encourage modular and flexible learning pathways, industry partners are increasingly eager to co-develop curricula, and digital tools provide platforms for interactive and collaborative learning.

2.5 IMPLICATIONS FOR TEACHING EXCELLENCE

By embedding learner-centred pedagogy into higher education, teaching excellence becomes more than a measure of academic expertise; it becomes a dynamic practice of facilitation, mentoring and co-learning. Academics serve as guides and coaches, cultivating learning environments in which students are active agents rather than passive recipients. In the Malaysian context, this approach resonates with the cultural and policy emphasis on lifelong learning, inclusivity and employability. The result is a pedagogy that not only improves learning outcomes but also equips graduates with the adaptability and resilience required in an unpredictable future.

3. TECHNOLOGY-ENHANCED LEARNING AND INDUSTRY 4.0 TOOLS

Technological transformation is reshaping higher education at an unprecedented scale. The convergence of artificial intelligence (AI), big data, the Internet of Things (IoT), robotics and immersive technologies represents both an opportunity and an obligation for universities. In the context of teaching excellence, technology-enhanced learning offers new ways to personalise education, engage learners interactively and ensure that higher education remains relevant to rapidly evolving professional landscapes (Bond et al., 2020).

3.1 TECHNOLOGY AS AN ENABLER OF INTERACTIVE LEARNING

Digital platforms can transform passive learning environments into interactive, engaging experiences. Video-based learning, interactive simulations, gamification elements and adaptive quizzes enable students to learn in ways that align with their cognitive preferences and pace (Bolliger et al., 2010). In Malaysia, universities increasingly deploy learning management systems (LMS) such as Moodle and Canvas to host blended and online courses. These systems are augmented with multimedia content, peer discussion forums, and analytics tools that allow instructors to track learner progress and intervene as needed. UiTM's implementation of smart classrooms, immersive learning spaces and data analytics labs exemplifies Education 5.0@UiTM's commitment to humanising technology through innovative yet ethical delivery systems (Mohd Salleh et al., 2020).

3.2 PERSONALISATION THROUGH ARTIFICIAL INTELLIGENCE AND DATA ANALYTICS

AI-driven platforms provide adaptive learning experiences by analysing student performance data and tailoring content accordingly. For instance, intelligent tutoring systems can adjust the difficulty level of tasks in real time, while chatbots can support learners by answering frequently asked questions. The use of big data analytics further enables institutions to identify patterns in student engagement and predict attrition risks, allowing timely interventions (Zawacki-Richter et al., 2019). Such innovations are integral to Education 5.0, where technology facilitates personalised, learner-driven pathways.

3.3 GAMIFICATION AND MOTIVATION IN HIGHER EDUCATION

Gamification has emerged as a powerful strategy to enhance student motivation and participation. By incorporating game mechanics such as badges, leaderboards and progress tracking into learning platforms, educators can encourage sustained engagement and persistence (Dichev & Dicheva, 2017). More importantly, gamification supports the learner-centred paradigm by making education more participatory and enjoyable without sacrificing academic rigour.

3.4 CYBERSECURITY AND ETHICAL CONSIDERATIONS

The widespread adoption of digital tools also raises important ethical and security concerns. As universities transition to cloud services, digital assessments and AI-powered platforms, they must safeguard sensitive student and research data against cyber threats (Ahmad et al., 2014). Cybersecurity policies, routine audits and staff training are therefore essential components of any digitalisation strategy. Additionally, ethical issues surrounding AI, such as algorithmic bias, transparency and the potential misuse of student data, may require clear regulatory frameworks and institutional accountability. In this respect, the Malaysian government's increasing attention to data governance complements the broader higher education transformation agenda.

3.5 EDUCATION 5.0 AS A FRAMEWORK FOR TECHNOLOGY INTEGRATION

The Education 5.0@UiTM initiative illustrates how universities can strategically integrate technology while preserving humanistic and ethical dimensions of education (UiTM, 2019). This framework advocates for holistic learning that develops not only digital competencies but also moral and social values. In practice, Education 5.0 encourages the integration of AI, robotics and IoT into teaching while ensuring that such tools support, rather than replace, meaningful human interactions. The result is a blended ecosystem in which technology facilitates creativity, critical thinking and collaboration. The framework positions technology as an enabler of empathy and empowerment, ensuring that digital transformation aligns with human values rather than replacing human interaction.

3.6 IMPLICATIONS FOR TEACHING EXCELLENCE

Technology-enhanced learning does not replace the role of academics but expands their capacity to design inclusive, interactive and future-oriented educational experiences. The challenge lies in ensuring equitable access: without reliable connectivity, adequate devices and digital literacy training, technology risks deepening existing inequalities. Hence, teaching excellence in the digital era requires both innovative pedagogy and structural commitments to inclusivity, security and ethics. When appropriately implemented, technology becomes not only a medium of instruction but also a catalyst for learner empowerment and institutional transformation.

4. COLLABORATIVE AND INTERDISCIPLINARY TEACHING MODELS

Collaboration and interdisciplinarity are at the heart of teaching excellence in the 21st century. Complex societal problems, from climate change to cybersecurity, cannot be solved within the confines of a single discipline. Universities must therefore foster environments where learners, educators and industry partners collaborate across boundaries to generate innovative solutions. This orientation reflects the “Transformative Learning Environment” pillar of Education 5.0@UiTM, which promotes collaboration across faculties, disciplines, and industries to cultivate holistic and employable graduates.

4.1 THE RATIONALE FOR COLLABORATIVE LEARNING

Collaborative learning emphasises peer-to-peer interaction, shared problem-solving and the co-construction of knowledge. Research shows that collaborative approaches enhance critical thinking, retention and communication skills while preparing students for teamwork in professional environments (Johnson & Johnson, 2014). For Malaysia, where national policy highlights employability and innovation, collaborative learning aligns directly with labour market demands for adaptable graduates.

4.2 INTERDISCIPLINARY TEACHING AND CURRICULUM DESIGN

Interdisciplinary approaches encourage students to view problems holistically. Malaysian universities are increasingly embedding interdisciplinary modules, such as environmental sustainability courses that draw on engineering, business and social sciences. These approaches echo the goals of Education 5.0, which situates learning at the nexus of knowledge, values and societal relevance (UiTM, 2019). By involving multiple faculties and industry stakeholders in curriculum design, universities can expose students to diverse perspectives while cultivating the ability to integrate knowledge across fields.

4.3 GLOBAL AND INDUSTRY PARTNERSHIPS IN COLLABORATIVE TEACHING

Technology-enhanced learning environments enable collaboration across borders. Virtual exchanges, joint online courses and industry-sponsored projects allow Malaysian students to engage with peers and experts globally. For example, collaborative online international learning (COIL) initiatives connect local institutions with international partners, fostering cross-cultural competence (Rubin, 2016). Similarly, partnerships with industry ensure that academic projects address real-world challenges, thereby bridging the gap between theory and practice.

4.4 INSTITUTIONAL CHALLENGES AND OPPORTUNITIES

Despite clear benefits, implementing collaborative and interdisciplinary teaching faces obstacles. Institutional silos, rigid faculty structures and limited incentives for cross-disciplinary work often hinder innovation. Faculty members may also lack experience in facilitating group-based learning or co-teaching across disciplines. However, opportunities are expanding: policy frameworks encourage university–industry partnerships, while digital platforms reduce logistical barriers to collaboration. The key lies in providing adequate institutional support, including recognition of interdisciplinary teaching in promotion criteria and funding for collaborative projects.

4.5 IMPLICATIONS FOR TEACHING EXCELLENCE

Collaborative and interdisciplinary approaches redefine teaching excellence as a collective endeavour. The “Inspiring Educators” pillar of Education 5.0@ UiTM underscores this collective ethos, positioning educators as mentors and co-learners who model adaptability and empathy. Rather than individual instructors delivering isolated content, teaching excellence emerges through networks of learners, academics and external stakeholders working toward shared goals. This approach nurtures not only knowledge but also soft skills such as leadership, empathy and cultural competence. By institutionalising collaborative practices, Malaysian higher education can prepare graduates to navigate and shape interconnected global societies.

5. THE ROLE OF ACADEMIC RESEARCH IN ENHANCING TEACHING

Academic research plays a vital role in advancing teaching excellence. Beyond producing new knowledge, research informs evidence-based pedagogical practices, drives innovation in curriculum design and evaluates the impact of educational reforms. In an era where accountability and quality assurance are paramount, research ensures that teaching practices are not only innovative but also effective.

5.1 RESEARCH-INFORMED PEDAGOGY

Research provides the evidence base for effective teaching strategies. Studies in cognitive psychology and educational technology, for instance, have revealed how students learn best in active, socially mediated and digitally enhanced contexts (Freeman et al., 2014). By embedding research findings into classroom practice, educators can adopt strategies proven to improve outcomes.

5.2 PRACTITIONER RESEARCH AND SCHOLARSHIP OF TEACHING AND LEARNING (SOTL)

The Scholarship of Teaching and Learning (SoTL) encourages educators to systematically investigate their own practice. In Malaysia, universities are increasingly promoting SoTL projects by providing grants to lecturers to experiment with new pedagogies and publish their findings. This has created a virtuous cycle in which teaching innovations are tested, refined, and disseminated across the sector. Education 5.0@UiTM formally integrates SoTL into its transformation agenda, supporting lecturers in conducting classroom-based research and embedding findings into course design.

5.3 INTERDISCIPLINARY AND APPLIED RESEARCH FOR EDUCATION 5.0

Research in the context of Education 5.0 goes beyond pedagogy to explore how emerging technologies and values-based frameworks can be integrated into higher education. Studies on gamification, AI ethics, and digital inclusivity directly contribute to improving the quality of teaching and learning. Applied research projects, often in collaboration with industry, also ensure that university teaching aligns with evolving workforce needs.

5.4 CHALLENGES IN LINKING RESEARCH AND TEACHING

Despite its potential, integrating research into teaching is not straightforward. Heavy teaching loads, limited funding and publication pressures often prevent academics from engaging deeply in pedagogical research. Additionally, institutional cultures that prioritise research outputs over teaching innovation may discourage investment in SoTL. Addressing these challenges requires policies that reward pedagogical research and recognise teaching excellence on par with disciplinary research achievements.

5.5 IMPLICATIONS FOR TEACHING EXCELLENCE

By grounding teaching in research, universities ensure that pedagogical decisions are informed, intentional and impactful. This not only enhances student learning outcomes but also elevates the status of teaching within academic careers. Research-informed teaching excellence thus represents a synergy of scholarship, practice and innovation that is essential for higher education in the era of Education 5.0.

6. POLICY, IMPLEMENTATION CHALLENGES AND SUPPORT SYSTEMS

Policies provide the structural backbone for advancing teaching excellence. In Malaysia, the Higher Education Plan 2025–2035 and the 13th Malaysia Plan underscore the government's commitment to modernising curricula, expanding digital infrastructure and supporting lifelong learning. However, translating these aspirations into reality requires overcoming significant implementation challenges.

6.1 POLICY DIRECTIONS FOR TEACHING EXCELLENCE

Current policies emphasise graduate employability, industry partnerships and digitalisation as key drivers of higher education reform. These align well with the principles of learner-centred pedagogy, technology integration and collaborative teaching. Policy initiatives also encourage modular and flexible learning pathways, such as micro-credentials and recognition of prior learning, which expand access and inclusivity (MOHE, 2025).

6.2 IMPLEMENTATION CHALLENGES

A descriptive analysis by Mohd Salleh et al. (2020) showed that while UiTM educators largely accept Education 5.0's strategic pillars, challenges persist due to infrastructure gaps, uneven digital readiness and entrenched assessment norms.

Several challenges threaten to slow progress:
- Digital divide: Unequal access to devices and internet connectivity disproportionately affects rural and underserved students.
- Capacity gaps: Not all institutions possess the infrastructure or expertise required for technology-enhanced learning.
- Faculty readiness: Many academics lack training in learner-centred pedagogy and digital pedagogy.
- Institutional inertia: Bureaucratic structures and traditional performance indicators can stifle innovation.

6.3 SUPPORT SYSTEMS FOR LEARNERS AND EDUCATORS

Effective implementation requires comprehensive support systems. For students, this includes financial aid, device loans, mental health services and academic coaching. For staff, continuous professional development in pedagogy and technology is essential, along with policies that promote wellbeing and recognise teaching excellence. Institutional support for teaching innovation, such as learning design centres and seed funding for pedagogical pilots, further strengthens reform efforts.

6.4 MONITORING AND ACCOUNTABILITY

Transparent monitoring mechanisms are critical to ensure that reforms achieve intended outcomes. Universities should track graduate employability, digital participation and student satisfaction as key performance indicators. Independent evaluations and regular policy reviews will help identify gaps and guide course corrections.

6.5 IMPLICATIONS FOR SUSTAINABLE TRANSFORMATION

Ultimately, teaching excellence in Malaysia depends on a supportive ecosystem that integrates policy intent with institutional capacity and individual commitment. Policies must be matched with resources, training and accountability to create conditions in which learner-centred, technology-enhanced and research-informed teaching can flourish. Education 5.0's guiding values of Adab (courtesy) and Amanah (trust) remind policymakers that humanising education requires empathy, integrity and accountability in implementation.

7. CONCLUSION

Teaching excellence in the era of Education 5.0 requires a fundamental paradigm shift in higher education. This paper has argued that excellence is best achieved by embedding learner-centred pedagogy, leveraging technology for interactive and inclusive learning, fostering collaborative and interdisciplinary models and grounding teaching in research-informed practice. In the Malaysian context, these transformations align with national policy frameworks such as the Higher Education Plan 2025–2035 and Education 5.0@UiTM, both of which aim to produce graduates who are skilled, adaptable, ethical and industry-ready. UiTM's Education 5.0@UiTM provides a practical blueprint for achieving this goal through its five pillars that integrate technological fluency with human-centred values. However, the success of these initiatives depends on addressing critical structural challenges such as the digital divide, uneven institutional capacity and varying levels of faculty readiness. If these challenges are effectively managed, Malaysian higher education can emerge as a regional leader in shaping adaptive, inclusive and future-ready learning ecosystems. Teaching excellence will no longer be confined to classroom performance; it will instead reflect universities' capacity to prepare graduates who can thrive and lead in a rapidly changing world.

8. SUGGESTIONS

This paper proposes the following suggestions:

- Strengthen professional development for educators in learner-centred and digital pedagogies.
- Integrate the five pillars of Education 5.0@UiTM across programme curricula and assessment design to ensure humanised, values-driven outcomes.
- Expand digital infrastructure and equity funds to ensure inclusive access to technology.
- Institutionalise collaborative and interdisciplinary teaching by incentivising cross-faculty projects and industry partnerships.
- Promote the Scholarship of Teaching and Learning (SoTL) to foster research-informed innovation in pedagogy.
- Ensure robust monitoring and accountability mechanisms to evaluate the impact of reforms.

Based on the most crucial factors identified in this study, namely, the integration of learner-centred pedagogy, technology in learning and research-informed teaching, future studies should focus on developing a comprehensive model of teaching excellence that empirically measures the impact of digital pedagogies on student engagement and graduate outcomes. New objectives may include evaluating institutional readiness and the long-term sustainability of Education 5.0 practices, using mixed-method or longitudinal approaches to capture both quantitative and experiential dimensions of teaching transformation.

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11. AUTHOR'S CONTRIBUTION

The sole author of this research prepared the data, contributed to the analysis of the results, and led the writing of the manuscript.

12. CONFLICT OF INTEREST DECLARATION

I certify that the article is the author's original work. 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. I testify that I have contributed significantly to the work, validity, and legitimacy of the data and its interpretation for submission to IJELHE.

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Unmasking Misconceptions: An Integrated Framework of Socratic Questioning and Alternative Assessment in Chemistry Education

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Abstract: *Conventional chemistry assessments often emphasise factual recall over conceptual understanding, allowing misconceptions to persist undiagnosed and unaddressed. This study investigated the effectiveness of an integrated approach combining Socratic questioning with alternative assessments to reveal and address student misconceptions in chemistry. A single-group quasi-experimental design was implemented with 43 Malaysian Form Four students on the topics of acids, bases, and salts. The approach included a two-tiered multiple-choice diagnostic test, concept mapping, and semi-structured interviews with the participants. The results revealed that while post-test scores showed improvement, alternative assessments provided a more comprehensive picture of student understanding. Two-tiered items distinguished between valid reasoning and correct answers based on flawed logic. Concept maps exposed persistent, flawed knowledge structures, such as linking 'salt' directly to 'neutral.' The interviews revealed the origins of these misconceptions, including the tendency to conflate 'strong' with 'concentrated' based on everyday experiences. The study demonstrates that these alternative assessment tools complement each other in providing a holistic diagnosis of students' understanding, revealing specific misconceptions that remain hidden in conventional scoring. The combined tools offer a complex view of student* *cognition that is unattainable through standard testing. A practical conceptual framework is proposed to help educators integrate Socratic dialogue with diagnostic assessment, shifting from assessment of learning to assessment for learning.*

Keywords: *Alternative Assessment, Concept Map, Conceptual Understanding, Misconceptions, Two-Tiered Test.*

1. INTRODUCTION

Science education emphasises cultivating deep conceptual understanding rather than mere rote memorisation, to nurture critical thinking and the capacity to apply knowledge in practical contexts. Nevertheless, this objective remains challenging to achieve in numerous chemistry classrooms, where traditional teaching and assessment methods often inadvertently hinder progress. A predominant focus on factual recall and algorithmic problem-solving can lead students to possess a tenuous, superficial understanding of abstract topics, making them vulnerable to forming robust alternative conceptions or misconceptions. This issue is particularly evident in acid-base chemistry, a fundamental topic that is beset by well-documented student misunderstandings. Common misconceptions include the persistent beliefs that all salts are neutral or that the terms "strong" and "concentrated" are interchangeable when describing acids (Cyril, 2017; Taber, 2018). Such misconceptions are not only challenging to rectify but also actively obstruct the development of sound scientific conceptual frameworks.

Exacerbating this problem is the inherent limitation of traditional assessments. Conventional tests, which predominantly use single-answer multiple-choice items, often fail to delve into students' reasoning (Sands, 2014). They can create an "illusion of understanding" by rewarding fortunate guesses or the application of flawed rules, leaving underlying misconceptions undiagnosed and unaddressed. To address this gap, this study proposes and examines an integrated framework that combines diagnostic assessment with targeted pedagogy. We propose that a multifaceted approach utilising alternative assessments—specifically, two-tiered diagnostic tests, concept maps, and semi-structured interviews—can reveal the specific nature and extent of hidden misconceptions among students.

Furthermore, we contend that Socratic Questioning is a uniquely appropriate pedagogical strategy to pair with diagnostic data, as its probing, inquiry-based nature is designed to challenge flawed reasoning and facilitate conceptual change. This study was guided by the following research questions to explore the efficacy of the integrated framework: What specific misconceptions regarding acids, bases, and salts are revealed through two-tiered tests, concept maps, and interviews that remain hidden in conventional scoring? How do these alternative assessment tools complement each other in providing a holistic diagnosis of students' understanding? How can Socratic questioning be effectively paired with these assessments to promote conceptual changes?

2. LITERATURE REVIEW

2.1 THE CENTRALITY AND CHALLENGE OF CONCEPTUAL UNDERSTANDING IN SCIENCE EDUCATION

Deep conceptual understanding is the cornerstone of scientific literacy, moving beyond rote memorisation to grasping core principles and their interrelationships (Hiebert & Lefevre, 1987). This understanding is particularly critical in chemistry, a subject characterised by abstract concepts that require students to integrate macroscopic, submicroscopic, and symbolic levels of thought (Taber, 2013; Perna & Wiedmer, 2019). The constructivist view of learning posits that students actively construct knowledge; however, this process is vulnerable to the development of robust and persistent alternative conceptions or misconceptions (Naeem Sarwar et al., 2024). These misconceptions are not mere factual errors but are often coherent, internally logical frameworks that differ from scientifically accepted models, ranging from simple misunderstandings to outright rejection of theory (Suprapto, 2020). Their resilience poses a significant challenge to meaningful learning in science education.

2.2 THE PERSISTENT PROBLEM OF MISCONCEPTIONS IN ACID-BASE CHEMISTRY

The topic of "Acids, Bases, and Salts" serves as a prime example of a domain in which misconceptions are particularly prevalent and well documented in both local and international contexts (Cyril, 2017; Chu & Hong, 2010). Research has consistently identified several key conceptual clusters within this topic that are prone to misunderstandings.

Macroscopic Properties: Students often hold erroneous beliefs about the observable properties of acids and bases, such as overgeneralizing the corrosiveness of all acids while underestimating the hazards of bases or misunderstanding the role of indicators (Elham et al., 2019).

Acid Strength: This is one of the most confusing concepts. Students frequently equate "strong acid" with "concentrated acid," and incorrectly use pH as a direct measure of strength, confusing the concepts of strength (degree of ionisation) and concentration (amount of solute per volume) (Cyril, 2017; Susilaningsih et al., 2019).

Neutralisation: Despite its seemingly straightforward nature, students exhibit deep-seated misconceptions, such as the belief that "all salts are neutral," that the resulting solution contains no H^+ or OH^- ions, or that only strong acids and bases can undergo neutralisation (Ivanoska & Stojanovska, 2021; Cyril, 2017).

Acid-Base Equilibrium: The abstract nature of equilibrium leads to misunderstandings, including the idea that the acidity constant is unaffected by temperature and that salts contain no hydrogen or hydroxyl ions (Cyril, 2017). A weak foundational understanding at this level can hinder the comprehension of advanced topics (Liliasari et al., 2018).

2.3 THE DIAGNOSTIC BLIND SPOT OF TRADITIONAL ASSESSMENT

Conventional assessment methods, such as standard multiple-choice tests, are often insufficient for diagnosing complex, layered misconceptions. They primarily assess factual recall and algorithmic problem-solving, creating an “illusion of understanding” (Caleon & Subramaniam, 2010; Fikri et al., 2022). Students may select the correct answer by guessing or using a flawed heuristic, even though their underlying reasoning is incorrect. This fundamental limitation underscores the need for assessment tools that can probe beneath the surface of a final answer to reveal the cognitive structures and justifications that define true conceptual understanding.

2.4 ALTERNATIVE ASSESSMENTS: A TRIANGULATED APPROACH TO DIAGNOSIS

To address the shortcomings of traditional tests, educators have turned to alternative assessments that provide a richer and more holistic diagnosis of student thinking.

Two-Tiered Diagnostic Tests: These instruments combine a multiple-choice question (first tier) with justification for that choice (second tier). This design is highly effective for identifying misconceptions because it requires students to reveal their reasoning and distinguish between factual luck and genuine understanding (Gurel et al., 2015). Their efficacy in uncovering hidden misconceptions has been demonstrated across various science subjects, including biology and chemistry (Taşçı, 2024; Ariyani & Rusilowati, 2023).

Concept Maps: As visual representations of knowledge structures, concept maps allow students to externalise the connections they perceive between concepts. They assess prior knowledge, the ability to link ideas, and the hierarchical organisation of knowledge, revealing gaps and erroneous links that written tests may miss (Schroeder et al., 2022; Novak & Gowin, 1984). Their utility in uncovering both scientific and alternative concepts in STEM education is well established (Wang, 2025).

Semi-Structured Interviews: Serving as a "gold standard" for qualitative diagnosis, interviews allow researchers to probe deeply into a student's knowledge, experiences, and attitudes (Alshenqeeti, 2014). They provide the "why" behind the answers given in tests and concept maps, offering nuanced insights into the origin and nature of misconceptions that other tools can only hint at (Ariyani & Widiyatmoko, 2015; Kristianti et al., 2022).

These tools are complementary to each other. Two-tiered tests efficiently screen for misconceptions across a cohort; concept maps visualise the structure of knowledge; and interviews explore the depth of knowledge. Using these methods in tandem enables triangulation, providing a robust, multifaceted diagnosis that is far more comprehensive than any single method.

2.5 FROM DIAGNOSIS TO CHANGE: SOCRATIC QUESTIONING AS A PEDAGOGICAL ENGINE

Identifying misconceptions is the first step, and the pedagogical challenge is to promote conceptual change. Posner's Conceptual Change Theory suggests that for a misconception to be replaced, learners must be dissatisfied with their existing conception, and the new concept must be intelligible, plausible, and fruitful (Amin et al., 2014). Socratic Questioning (SQ) is a powerful pedagogical strategy directly aligned with this goal.

SQ is a disciplined, inquiry-based dialogue that probes the meaning, justification, and logical strength of students' claims (Oyler & Romanelli, 2014). It is not merely a method of questioning but a way to guide students to reflect on their own thinking. By exposing contradictions in their reasoning, SQ induces the dissatisfaction necessary for conceptual change. It then scaffolds the process of making new concepts intelligible and plausible by guiding students to construct their own understandings. Studies have shown that SQ fosters critical thinking and creates an inquiry-focused classroom environment (Duran & Dokme, 2016), and its structured application has been effective in improving cognitive outcomes in other fields (Clark & Egan, 2018).

2.6 SYNTHESISING THE FRAMEWORK AND IDENTIFYING THE GAP

The literature reveals a clear pathway: acid–base chemistry is plagued by persistent misconceptions that are often invisible to traditional assessments. A triad of alternative assessments, including two-tiered tests, concept maps, and interviews, can effectively unmask these hidden misunderstandings. Furthermore, Socratic Questioning provides a theoretically sound pedagogical mechanism for disrupting misconceptions and facilitating conceptual change. However, although these elements have been studied in isolation, research on their deliberate integration into a cohesive framework is lacking. The present study seeks to fill this gap by proposing and investigating an integrated model in which alternative assessments serve as the diagnostic core for identifying misconceptions. Socratic questioning serves as a pedagogical engine for identifying and resolving them. The synergy between precise diagnosis and targeted intervention offers a promising approach to achieving deep, meaningful conceptual change in chemistry education.

3. METHODOLOGY

3.1 DESIGN AND CONTEXT

This study used a single-group, time-series quasi-experimental approach in which one intact Form 4 Chemistry class served as its own comparison over time. The design was chosen because of access constraints that prevented a parallel control group and because it allows multiple observations before and after the instructional intervention (Socratic Questioning, SQ) during the Acids, Bases, and Salts (ABS) unit in the Malaysian KSSM curriculum.

3.2 PARTICIPANTS

The sample comprised N = 43 Form 4 students (16 male, 27 female) enrolled in Chemistry and present during the intervention. Participation was voluntary and aligned with standard school protocols.

3.3 INSTRUMENTS

Three classroom-compatible tools were used for assessment and data collection.

Diagnostic Tests: The study used a two-part assessment to evaluate students' comprehension of acid-base chemistry and identify misconceptions. A pre-test of eight true/false questions, derived from a previous assessment (Elham et al., 2019), gauged students' prior knowledge. Subsequently, a post-test with 18 questions, including 10 multiple-choice and eight two-part questions, was conducted, based on another assessment (Damanhuri et al., 2016). The two-part questions were significant as they required students to select an answer and provide a rationale, helping identify misconceptions that conventional scoring might miss. To ensure validity and reliability, the tests were reviewed by experts. The head of the chemistry panel verified that the questions aligned with the curriculum and measured the intended constructs. A pilot study with a comparable class identified ambiguous questions, assessed test duration, and performed preliminary analysis. This process ensured test clarity and reliability in practical settings. Although the differing content of pre- and post-tests posed challenges for reliability checks, adapting the tests from validated tests and a pilot study made them reliable for collecting meaningful data.

Concept maps: Concept mapping was employed as a methodological tool to understand students' cognitive processes by providing a visual representation of their thinking. Two mapping sessions were conducted—before and after instruction—to assess changes in students' knowledge of acids, bases, and salts. Students were given key concepts and asked to construct diagrams illustrating the interconnections among them. The concept maps were evaluated using Markham et al.'s (1994) framework. Maps were first categorised as valid or invalid based on task alignment. Valid maps were then assessed for complexity, receiving low, medium, or high scores based on the accuracy of concepts and organisation, including coherent structure and meaningful linkages. The framework evaluated conceptual accuracy, helping identify correct and incorrect understandings in students' thinking.

Semi-structured interviews: Interviews were conducted after tests and concept mapping sessions to understand student thinking. Six students were selected to represent low, medium, and high levels of understanding. This helped compare how students at different levels faced challenges and showed strengths. The interviews focused on three areas: understanding why students gave certain test answers beyond mere correctness; examining how students interpreted terms such as “strong,” “neutral,” and “concentration” to identify misunderstandings; and having students explain the changes they made to their concept maps. This approach revealed how students built knowledge and where they succeeded or struggled in learning.

3.4 PROCEDURE

The sequence was as follows: conventional ABS instruction → pre-test + pre-concept map → instruction with SQ embedded across ABS lessons → post-test + post-concept map → semi-structured interviews with selected students. The SQ was used continuously in lessons to elicit assumptions, probe mechanisms (e.g., ionization, hydrolysis), and contrast everyday and scientific meanings (e.g., strong/weak vs concentrated/dilute).

3.5 DATA ANALYSIS

Data analysis emphasised straightforward summaries suited to the classroom research. Diagnostic test data were analysed using descriptive statistics (e.g., mean, median, range) and concept-level percentages correct to show changes from pre- to post-instruction. Item-level patterns in the two-tier portion were noted to indicate where justifications aligned or conflicted with scientific reasoning. Concept maps and interview data were analysed using thematic analysis, focusing on the presence or absence of key conceptual links (e.g., relationships among strong/weak, ionisation, pH, concentration; neutralisation, and salt hydrolysis) and students’ explanations of their choices. Themes from the maps and interviews were read alongside the test patterns to provide a coherent picture of students’ conceptual understanding and misconceptions following the SQ-supported unit.

4. FINDINGS

This study employed an integrated framework of Socratic questioning and alternative assessment to diagnose and address Form 4 students’ misconceptions of acid-base chemistry. The findings are presented according to three research questions, synthesising data from diagnostic tests, concept mapping, and interviews.

4.1 SPECIFIC MISCONCEPTIONS REVEALED BY ALTERNATIVE ASSESSMENTS

Conventional scoring of the diagnostic post-test showed an overall improvement, with average scores increasing by 79.5%. However, the two-tiered tests, concept maps, and semi-structured interviews revealed persistent misconceptions that simple multiple-choice scoring would have concealed. The triangulation of these data sources was critical to moving beyond superficial performance metrics and uncovering the robust, often hidden architecture of student misunderstandings. These misconceptions were predominantly clustered in four key conceptual areas:

Neutralisation: This was the most prevalent and deeply held misunderstanding. Interviews revealed a tenacious belief that "all salts are neutral," often justified by daily experiences with table salt. Students also held the alternative conception that at the end of a neutralisation reaction, the solution is "empty," containing neither H^+ nor OH^- ions.

Acid Strength: A significant conflation of concepts was observed. Students consistently equated "strong acid" with "concentrated acid." Furthermore, the two-tiered test and interviews showed that many studies used pH as the sole indicator of acid strength, misunderstanding the distinction between strength and concentration.

Macroscopic Properties: Although the surface-level understanding was good, deeper probing uncovered erroneous ideas. Some students believed that the mere presence of a hydrogen atom in a molecular formula (e.g., CH_4) implied acidity. Concept maps and interviews also showed a tendency to underestimate the corrosivity of bases, perceiving them as inherently less harmful than acids.

Acid-Base Equilibrium: This was the least frequently reported area of misconception, but interviews revealed critical gaps, such as the belief that the pH of pure water remains constant, regardless of temperature.

A compelling example of the power of triangulation is found in the data on macroscopic properties. While 95.3% of students correctly identified that soaps contain alkalis (post-test B7), the two-tiered reasoning revealed that 34.9% justified this with misconceptions like "Alkalis are soapy and so can wash away stains." This critical discrepancy between a factually correct answer and an incorrect underlying rationale, visible only through a two-tiered instrument, demonstrates that conventional assessments can significantly overestimate conceptual mastery. Subsequent interviews confirmed that these vernacular associations ("soapy" = "alkali") were deeply ingrained, highlighting the qualitative value of interviews in explaining the quantitative patterns found in the tests.

4.2 COMPLEMENTARY ROLE OF ALTERNATIVE ASSESSMENT TOOLS

The three alternative assessment instruments functioned synergistically to provide a holistic diagnosis that no single tool could achieve. This multifaceted approach effectively triangulated the data, building a robust evidence base in which the strengths of one instrument compensated for the limitations of the others. To surface misconceptions masked by conventional scoring, we aligned the evidence across tools, as summarised in Table 1.

Target Misconception	Two-Tier Evidence	Concept Map Evidence	Interview Evidence	Summary Inference
Strength vs. Concentration/ pH	B4 justifications assign partial ionisation to strong acids; pH is treated as a direct proxy for "strength."	Missing/incorrect links among strong/ weak–ionisation–pH–concentration.	Language conflation of terms; limited prior foundation.	Conceptual conflation persists under totals; it requires ionization-centred SQ + map revision.
Neutralisation → Neutral Salt	Justifications assume neutrality irrespective of the parent acids/ bases.	One-step chains lacking parent strength/ hydrolysis nodes.	The generalisation "All salts are neutral" is based on daily experience.	The hidden schema explains the errors; SQ should force conditional predictions and hydrolysis mapping.
Heuristic Cleaning	B7 favours "soapy/alkali cleans" or "corrosive/acid cleans."	Mechanism nodes (e.g., saponification) are absent or unlinked to the substance class.	Home experiences narratives dominate the scientific mechanism.	Experience-first reasoning overrides mechanism; SQ to elicit evidence and counterexamples.
Composition-as-Definition	B5: "Any H compound is an acid."	Sparse/absent node for ionisation vs. composition.	Definition learned by keyword cues (e.g., presence of 'H').	Requires explicit SQ separating composition from behaviour + exemplars/ non-exemplars.

Table 1. Triangulation of Evidence from Alternative Assessments to Unmask Hidden Misconceptions

The key takeaway here is that different tools found the same hidden thinking patterns that regular tests missed. For example, a student might say “soap is basic” on a regular test. However, a two-part test showed they thought “soapy = alkali.” A concept map showed they did not connect this to how cleaning works. An interview showed this idea came from everyday life, not science. This detailed analysis helps teachers know where to focus their questions to fix misunderstandings. It helps students truly understand, not just give the right answers.

4.3 SOCRATIC QUESTIONING AS A CATALYST FOR CONCEPTUAL CHANGE

The integration of Socratic questioning proved effective in facilitating conceptual change, serving as both a pedagogical intervention and a metacognitive scaffold within assessment. The study design enabled clear triangulation of outcomes, showing that Socratic questioning directly addressed misconceptions identified by diagnostic instruments. Quantitative and qualitative data corroborated their positive impact. Improved test scores and increased complexity of concept maps evidenced their effect on cognitive gains. Survey results (mean > 3.0 across all domains) and interviews indicated that Socratic questioning enhanced critical thinking and engagement. Students reported that it “challenges you to think critically instead of just getting the answers straight away” and motivated them to prepare more thoroughly for class. The mechanism for conceptual change was evident in how Socratic questioning established a feedback loop with assessments. The probing questions directly mirrored the diagnostic process of two-tier tests and interviews, training students to question their assumptions and justify reasoning.

This study claims that Socratic questioning cultivates metacognitive skills necessary for students to self-diagnose misunderstandings. During lessons, students deconstructed their alternative frameworks. This created an environment where identifying misconceptions became the starting point for Socratic dialogue aimed at reconstructing scientifically sound concepts. In conclusion, triangulated data present a compelling case for this framework. The alternative assessments provided a “map” of misconceptions, while Socratic questioning served as the “engine” for conceptual journeying, guiding students from initial alternative conceptions toward scientifically valid understanding. This cycle of diagnosis and inquiry empowers students to become agents of conceptual change.

5. DISCUSSION

5.1 EFFICACY OF SOCRATIC QUESTIONING

The study demonstrated that Socratic questioning is a highly effective method for enhancing students' conceptual understanding, particularly in domains that require deeper conceptual reasoning, such as neutralisation, acid strength, and acid-base equilibrium. Socratic questioning prompts students to engage in critical thinking, formulate explanations, and justify their reasoning, thereby fostering deeper, more scientifically accurate comprehension.

Although some misconceptions regarding macroscopic properties, acid strength, neutralisation, and acid-base equilibrium persisted even after the Socratic Questioning intervention, notable improvements were observed in the students' capacity to construct new knowledge and conceptual understanding. Students reported positive outcomes, including enhanced critical thinking skills and improved comprehension, acknowledging that Socratic questioning challenged them to think more deeply rather than passively receiving answers (Amdan, 2025). By encouraging justified and analytical conclusions, this approach directly supports the objective of eliciting thorough explanations and justifications, thereby fostering conceptual growth among preservice teachers.

5.2 STRUCTURE OF KNOWLEDGE

Enhancements in the structure of knowledge, as evidenced by changes in concept maps, suggest improved organisation and interconnections, which are essential for sustained comprehension. Post-intervention analysis of the concept maps revealed a significantly positive trend. The percentage of invalid concept maps decreased by 63.6% (from 11 to 4) following the intervention. The number of valid concept maps increased by 21.9% (from 32 to 39). High-score concept maps (with scores of 20) showed an impressive 87.5% increase (from 8 to 15). A detailed comparison of students' concept maps from pre- to post-intervention illustrated this shift in understanding (ibid., 2025). Initially, Student X constructed a simple and direct concept map with limited branching and no clear hierarchy. After the intervention, the students' concept maps became significantly more complex and densely populated, displaying more branching and a clearer hierarchy of concepts. This transformation signifies deeper understanding and improved acquisition and retention of new knowledge, demonstrating that Socratic Questioning helps students construct a robust conceptual understanding and a strong foundation of baseline knowledge. Concept maps effectively assess students' prior knowledge, their ability to link concepts, and how they organise information, thereby revealing gaps and enhancing their conceptual understanding.

5.3 PERSISTENT PITFALLS

Despite the overall positive impact of Socratic Questioning, the concept of acid strength consistently presents a persistent pitfall for students. Students frequently conflated pH, concentration, and strength, indicating a fundamental misunderstanding. For example, students often expressed beliefs such as, "I think pH indicates if acid is strong" and "strong acid is a concentrated acid". These results clearly illustrate the confusion between distinct chemical properties. Every day, heuristics and vocabulary exacerbate this challenge. The vernacular barrier, where words like 'strength', 'concentrated', and 'diluted' are often used synonymously in daily language, directly influences students' scientific understanding and contributes to these misconceptions. Without guided interrogation, these everyday associations can mislead students, making it difficult for them to grasp the precise scientific definitions and relationships between pH, concentration, and acid strength. The interviews conducted in this study identified acid strength as a concept that students retained a high level of misconception about.

6. IMPLICATIONS AND RECOMMENDATIONS

The significant implications and recommendations of the findings of this study are as follows:

6.1 IMPLICATIONS FOR CLASSROOM TEACHERS

This study demonstrates that conceptual understanding is multifaceted and cannot be gauged using conventional tests alone. Therefore, teachers must adopt a diagnostic mindset and use a toolkit of strategies to uncover and address the root causes of student misunderstandings. Table 2 summarises the key recommendations for direct classroom applications, followed by a detailed rationale for each.

Misconception Focus	Socratic Questioning (SQ) Prompt Example	Complementary Classroom Activity
Neutralisation & Salt pH	"Will the salt from a strong acid and a weak base be acidic, basic, or neutral? Justify based on the ions present."	Use pH probes to test solutions of different salts (e.g., NH_4Cl, CH_3COONa, NaCl) and map results against parent acid/base strength.
Acid Strength vs. Concentration	"How can a 0.1 M HCl solution be more acidic than a 2.0 M CH_3COOH solution? Explain at the particle level."	Use particle diagrams to contrast the ion concentration in a strong-dilute acid versus a weak-concentrated one.
Vernacular Traps (e.g., 'Strong')	"What does 'strong' mean in everyday language? How does its scientific meaning in chemistry differ?"	Co-construct a "Concept Contrast Wall" or glossary explicitly comparing terms like Strong/Weak (ionisation) vs. Concentrated/ Dilute (amount).
Making Thinking Visible	"Based on our discussion, how would you now revise the connections in your initial concept map?"	Implement 5-minute concept map tasks at the start and end of a lesson to externalise and track changes in conceptual links.

Table 1. Triangulation of Evidence from Alternative Assessments to Unmask Hidden Misconceptions

Methodological Rationale: Implementing Targeted Socratic Questioning The SQ prompts in Table 2 were designed to move beyond factual recall and probe reasoning. For instance, the question of salt pH forces students to apply the concept of hydrolysis, which is often the missing link in understanding why neutralisation does not always produce a neutral solution. Active cognitive engagement is crucial for disrupting flawed mental models.

Theoretical Rationale: Scaffolding Language and Formative Assessment. Complementary activities are grounded in constructivist and language-aware pedagogy. The “Concept Contrast Wall” directly addresses the theoretical implication that vernacular meanings interfere with the formation of scientific concepts. Similarly, using quick concept maps as formative assessment tools aligns with the methodological implication that thinking must be externalised for assessment and refinement. Providing sentence stems (e.g., “I know it is a strong acid because it ______ completely in water...”) scaffolds the language that all students need to articulate complex chemical reasoning.

6.2 IMPLICATIONS FOR DEPARTMENTS AND TEACHER EDUCATORS

The effective implementation of Socratic Questioning (SQ) and alternative assessment requires systemic support beyond individual teachers. School departments and teacher education programs must build capacity by moving beyond workshops to foster sustained, collaborative, skills-based professional learning focused on pedagogical techniques and assessment literacy.

Micro-skills Professional Development: Replace theoretical sessions with practical training focused on SQ implementation. This includes practising question stems, maintaining productive wait time, and—through video clubs or peer observation—developing the skill to use student responses to probe rather than lead to predetermined answers.

Cultivating a Diagnostic Assessment Culture: Shift from solely summative assessment to an integrated diagnostic approach. Teachers can collaboratively design and analyse students' responses to two-tier questions to identify patterns of misconceptions. It is critical to legitimise qualitative data from concept maps and student interviews as evidence of understanding, granting them equal status to quantitative test scores.

These concerted efforts help institutions create an environment where teachers receive continuous support in developing skills to diagnose and address student misunderstandings.

6.3 IMPLICATIONS FOR CURRICULUM AND NATIONAL ASSESSMENT

To maximise engagement without reinforcing flawed intuitive reasoning, curriculum and assessment design must adopt a more critical approach to real-world context. While using familiar examples such as soaps, detergents, and soil pH is highly engaging, it is pedagogically insufficient if it does not actively confront the heuristic assumptions these contexts can trigger. Theoretically, this necessitates a curriculum that deliberately pairs these contexts with data and counterexamples; for instance, following a lesson on neutralisation with an investigation into the pH of various salt solutions to challenge the assumption that all salts are neutral. Methodologically, this principle must be extended to high-stakes assessments. By innovating examination design to include items that probe reasoning and justification, signalling that conceptual understanding is valued over rote recall, educational systems can create a powerful feedback loop that incentivises teachers to employ these deeper, more critical teaching practices throughout the academic year.

7. CONCLUSION

This study demonstrates the profound efficacy of an integrated framework that strategically pairs alternative diagnostic assessments with the pedagogical power of the Socratic method. Moving beyond the limitations of conventional testing, the triangulation of two-tiered tests, concept maps, and interviews provided a distinct yet holistic map of student cognition, unmasking specific and persistent misconceptions in acid-base chemistry that would otherwise remain hidden. In addition to being a diagnostic tool, this multifaceted approach serves as a vital precursor to targeted interventions. The findings affirm that Socratic questioning, when informed by rich diagnostic data, acts as a powerful engine for conceptual change, actively engaging students in critical reflection and the reconstruction of their knowledge. The implications are significant for science educators, suggesting a necessary shift towards classroom practices that are not only inquiry-based but also diagnostically driven. Future research should explore the scalability of this framework across diverse educational contexts and its longitudinal impact on the retention and application of scientific concepts. Ultimately, this research underscores that the path to robust scientific literacy requires both a precise compass to diagnose misunderstandings and deliberate pedagogy to guide students toward more accurate and enduring understanding.

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10. AUTHOR'S CONTRIBUTION

Author1 supervised the entire study, wrote the write-up, and finalised the article. Author2 carried out the field work, prepared the literature review, and carried out the analysis as well as the interpretation of results.

11. CONFLICT OF INTEREST DECLARATION

We certify that the article is the author's and co-authors' original work. 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 attest that all authors have contributed significantly to the work, the validity and legitimacy of the data, and its interpretation for submission to IJELHE.

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The Importance of Internet of Things (IoT) Applications in Advancing Teaching and Learning in Property Management Practices

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Abstract: *The integration of the Internet of Things (IoT) into property management is reshaping professional practices and transforming how future practitioners are taught and trained. This study examines the importance of IoT applications in advancing teaching and learning within property management education. The research objectives are to identify key IoT attributes, evaluate their relevance to property management pedagogy, and analyse how these attributes can be embedded into teaching strategies and learning outcomes. A mixed-methods approach was employed, involving a literature review, semi-structured interviews with three industry professionals, and an online survey of 306 respondents. The findings highlight that IoT attributes such as reducing carbon emissions, improving work productivity, enhancing tenant–management relationships, strengthening safety and security, and ensuring effective indoor air quality management are not only significant in professional practice but also serve as valuable content for teaching and curriculum design. Furthermore, attributes such as space utilisation analytics, cloud-*

based maintenance, real-time communication, and technological innovation showed medium to strong correlations with property management practices (r = 0.482), underscoring their pedagogical relevance. These findings suggest that integrating IoT concepts into property management teaching enhances students' digital literacy, practical understanding, and readiness for industry transformation. Overall, the study helps bridge the gap between industry innovation and higher education by demonstrating how IoT can be leveraged to enrich teaching and learning in property management.

Keywords: *Internet of Things (IoT), Teaching and Learning, Property Management Practices*

1. INTRODUCTION

In recent years, the Internet of Things (IoT) has emerged as a transformative trend within the real estate and property management sector. IoT technologies enable innovative solutions to longstanding challenges, including data reporting frameworks, predictive maintenance, risk management, cost optimisation, and energy efficiency (Li & Yu, 2022; Zhang et al., 2021). By integrating interconnected devices and smart sensors, IoT enables real-time monitoring, automation, and analytics that enhance operational efficiency and sustainability in building management (Gubbi et al., 2013). Consequently, the adoption of IoT applications provides new opportunities for both building occupants and management personnel to improve productivity, comfort, and safety (Kumar & Mallick, 2018).

Beyond its operational advantages, the integration of IoT technologies has become increasingly significant in advancing teaching and learning practices in property management education. Embedding IoT applications into academic curricula and professional training programmes allows learners to engage with real-time data, simulate smart building systems, and develop competencies relevant to the evolving digital property landscape (Al-Fuqaha et al., 2015; Singh et al., 2020). This pedagogical shift supports experiential learning and strengthens the link between theoretical knowledge and industry practice, preparing future property managers to make informed, data-driven decisions in technologically advanced environments (Lim & Nordin, 2023).

Nevertheless, the level of awareness and adoption of IoT applications in property management remains limited. Many stakeholders remain sceptical or uncertain about the importance and relevance, the implementation costs, and the long-term benefits of IoT integration (Tan & Lee, 2021). Such perceptions may hinder the digital transformation of the property management industry and impede the evolution of innovative teaching and learning strategies within the field. Therefore, it is imperative to enhance awareness, training, and research concerning the applications and pedagogical potential of IoT to foster a more adaptive, technology-driven approach to property management practice and education (Chong et al., 2022).

2. RESEARCH BACKGROUND

The Internet of Things (IoT) paradigm has been increasingly applied across sectors, including manufacturing, logistics, healthcare, and urban infrastructure. By enabling the interconnection of devices and systems, IoT extends the potential of smart technologies to remotely monitor, analyse, and optimise complex operations, including those in Intelligent Transportation Systems (ITS), smart industries, and smart cities (Chen, 2021). In property management, IoT represents a significant innovation in how buildings and assets are managed, maintained, and monitored.

Property management can be broadly defined as the professional administration of residential, commercial, or industrial assets on behalf of property owners, to preserve and enhance asset value while ensuring operational efficiency and tenant satisfaction (Anderson & Courage, 2021). Traditionally, the scope of property management has focused on essential operational activities such as security, cleaning, and maintenance (Yiu & Yau, 2006). These functions, whether managed in-house or outsourced to third-party service providers (Oyedele, 2013), have often relied heavily on manual supervision, paper-based reporting, and reactive problem-solving approaches.

The emergence of Information and Communication Technology (ICT), particularly IoT, has transformed these conventional practices by enabling the integration of connected devices and data-driven decision-making. Through machine-to-machine (M2M) communication and sensor-based monitoring systems, IoT facilitates real-time data collection and analysis to support predictive maintenance, energy optimisation, risk management, and enhanced user experience (Zhang et al., 2021). This digital advancement not only improves the efficiency and transparency of property management processes but also creates new opportunities for strategic management and sustainability initiatives.

Importantly, the growing role of IoT in property management underscores the need to advance teaching and learning practices in this field. As the industry shifts toward digital transformation, property management education must evolve to equip learners with the technological literacy, analytical capabilities, and problem-solving skills required to manage smart buildings effectively (Lim & Nordin, 2023). Integrating IoT applications into academic curricula and professional training provides learners with experiential exposure to real-world technologies, fostering competency in data interpretation, system integration, and digital asset management. This approach bridges the gap between theory and practice, ensuring that graduates are well prepared to navigate and lead in an increasingly data-driven property sector.

Therefore, understanding the significance of IoT in both operational and educational contexts is crucial for the future of property management. The effective integration of IoT-based applications into teaching and learning can accelerate innovation, strengthen professional readiness, and help develop a technologically adept workforce capable of sustaining the real estate industry's competitive and sustainable growth.

3. PROBLEM STATEMENT

Previous studies have examined the emerging challenges in the property sector and the potential of Internet of Things (IoT) applications to address them (Mehta, 2021). Despite the growing recognition of IoT as a transformative technology, there remains a dearth of research exploring its actual significance in enhancing property management practices, particularly from the perspective of teaching and learning integration. While numerous studies have highlighted the operational and sustainability benefits of IoT implementation, limited scholarly attention has been paid to how these technological advancements can be incorporated into property management education to prepare future professionals for the industry's evolving digital landscape.

Among the critical challenges in the property sector are climate change mitigation, real-time energy management, and indoor air quality control—all of which IoT technologies can effectively address. Climate change mitigation has been recognised as one of the most pressing global issues, including in Malaysia, due to its impact on sustainability and urban development (Abd El-Mawla et al., 2019). The growing emphasis on environmental, social, and governance (ESG) performance has prompted the real estate industry to adopt innovative, technology-driven strategies to reduce carbon emissions (Malmodin & Bergmark, 2015). Since inefficient energy consumption is a major contributor to carbon emissions and rising operational costs, IoT-enabled systems offer solutions for monitoring, optimising, and automating energy use in real time (Carletti et al., 2017). Real-time energy use and management remain uncertain or poorly implemented in many traditional property management operations, often resulting in budget inefficiencies and reduced building performance (Malmodin & Bergmark, 2015).

Additionally, indoor air quality management poses a persistent challenge in building operations, as appliances and materials within facilities may release harmful chemicals that circulate through air systems (Warren, 2011). IoT-supported technologies allow for continuous air quality monitoring through sensor networks that transmit data to facility managers and health personnel via wireless communication systems (Wolf & Serpanos, 2018). These applications highlight the capacity of IoT not only to optimise building performance but also to ensure healthier and more sustainable living and working environments.

However, while the practical applications of IoT in addressing property management challenges are well documented, translating these innovations into teaching and learning practices remains limited. Future property managers must possess not only managerial and technical knowledge but also digital competencies to analyse, interpret, and apply IoT-generated data to improve building operations and sustainability outcomes. Without embedding IoT literacy and practical exposure into educational curricula, there is a risk of producing ill-equipped graduates to manage smart properties or lead digital transformation initiatives in the real estate sector (Lim & Nordin, 2023).

Thus, this study seeks to address the gap by examining the role of IoT applications in advancing teaching and learning in property management. It aims to highlight how IoT can serve as both an operational tool and an educational platform that bridges theoretical understanding with real-world application to enhance sustainability, efficiency, and professional readiness in the property management discipline.

4. AIM AND OBJECTIVES OF THE RESEARCH

This research aims to determine the importance of Internet of Things (IoT) applications in advancing teaching and learning in property management practices in Malaysia. The specific objectives are as follows.

To identify the importance of Internet of Things (IoT) applications in advancing teaching and learning in property management practices in Malaysia.
To determine the importance of attributes of Internet of Things (IoT) applications in advancing teaching and learning in property management practices in Malaysia.

To analyse the correlation between the attributes of Internet of Things (IoT) applications in advancing teaching and learning with different aspects of property management practices in Malaysia.

5. LITERATURE REVIEW

Several key aspects of the importance of IoT applications in advancing teaching and learning in property management are reviewed as follows.

5.1 PROPERTY MANAGEMENT

Property management is the process of managing and maintaining third-party-owned properties, with the property manager's role being to ensure the property retains its value and generates income for the benefit of the owner and users. This involves two main categories of maintenance: planned and unplanned, which are conducted based on the specific needs, functions, and designs of different property types (Kaur & Solomon, 2021).

From a teaching and learning perspective, understanding these management categories forms the foundation of property management education. Integrating IoT technologies in the curriculum enables students to visualise and simulate maintenance operations through real-time data monitoring and digital platforms. Such experiential learning using IoT-based tools prepares students to manage diverse property assets more effectively, reflecting real industry practices.

5.2 ATTRIBUTES OF INTERNET OF THINGS (IOT) APPLICATIONS IN PROPERTY MANAGEMENT PRACTICES

IoT applications in property management encompass various attributes that have significant implications for both professional practice and academic training. These include space utilisation and data analytics (Korzun et al., 2015), cloud-based maintenance systems (Lee et al., 2016), energy control and management (Omar et al., 2015), technological innovation in the real estate sector (Zhen, 2012), and real-time communication (Dusadeerungsikul & Nof, 2021).

Embedding these attributes into teaching and learning modules fosters data-driven decision-making skills, technological literacy, and innovative problem-solving, which are essential for future property managers.

5.2.1 SPACE UTILISATION AND DATA ANALYTICS

Space utilisation refers to the automated process of identifying and optimising the use of facilities by relocating operations or assets based on available space (Pierce & Knecht, 2009). IoT systems and analytics allow property managers to collect and analyse data on occupancy, usage, and energy patterns in real time (Bolla et al., 2011).

In academic contexts, these IoT applications enhance teaching by enabling students to analyse live or simulated building data and practice decision-making related to space management. Through such experiential learning, students develop critical thinking and analytical skills, bridging the gap between theoretical knowledge and industry-based applications.

5.2.2 CLOUD-BASED FOR PROPERTY MAINTENANCE

Cloud-based systems enable property managers to access property management software remotely without physical servers (Cloud Secure Tech, 2021). These platforms, such as AppFolio, integrate maintenance, accounting, and advertising management into a single interface. Future developments may involve integrating Geographic Information Systems (GIS), Virtual Reality (VR), and network technologies to enhance service quality (Christudason, 2008).

For teaching and learning, cloud-based applications provide interactive digital environments for students to simulate maintenance workflows, manage property databases, and collaborate on projects remotely. This technology-driven approach cultivates digital competency, teamwork, and adaptability skills increasingly demanded in the modern property management industry.

5.2.3 ENERGY CONTROL AND MANAGEMENT

Buildings rely heavily on electricity, and improving energy efficiency has become a global priority (Mariano-Hernández et al., 2021; Al-Rakhami et al., 2019). Building Energy Management Systems (BEMS) integrate sensors and analytics to improve energy performance (Bonilla et al., 2018).

In educational contexts, incorporating IoT-based BEMS into property management training allows students to observe real-time energy data, analyse consumption trends, and propose efficiency strategies. Such integration promotes sustainable thinking and environmental responsibility among learners, aligning academic outcomes with green property management practices.

5.2.4 TECHNOLOGICAL INNOVATION IN THE REAL ESTATE SECTOR

Technological innovation is interdependent and continuously evolving through interaction with other technologies (Coccia, 2018; Ulamen & Bergek, 2021). In the real estate sector, PropTech integrates IoT, Artificial Intelligence, Blockchain, Machine Learning, 5G, and data analytics (Srivastava, 2021).

Embedding PropTech innovations in teaching supports technology-enhanced learning, where students explore cutting-edge tools to manage assets, analyse markets, and simulate decision-making. This approach fosters innovation, creativity, and digital fluency, ensuring graduates are ready for the dynamic demands of smart property management environments.

5.2.5 REAL-TIME COMMUNICATION

Real-time communication underpins IoT functionality by ensuring timely, accurate, and efficient system responses (Underwood, 2018; Dietrich, 2010). In property management, it enables real-time monitoring, predictive maintenance, and rapid reporting (Carli et al., 2017).

For teaching and learning, real-time communication systems allow students to interact with live dashboards, monitor maintenance alerts, and participate in real-time decision simulations. These immersive educational experiences cultivate situational awareness, technical proficiency, and immediate problem-solving skills as key capabilities for managing smart buildings and IoT-integrated properties.

6. THE IMPORTANCE OF INTERNET OF THINGS (IOT) APPLICATIONS IN ADVANCING TEACHING AND LEARNING IN PROPERTY MANAGEMENT PRACTICES

This study offers a comprehensive explanation of the importance of Internet of Things (IoT) applications in property management and their potential to advance teaching and learning in the discipline. A comprehensive review of prior research indicates that IoT technologies are increasingly recognised for their ability to reduce carbon emissions, enhance tenant-management relationships, improve indoor air quality (IAQ), and strengthen safety and security systems in buildings. These applications not only contribute to efficient and sustainable property management but also represent critical areas for developing the knowledge and skills of future property managers.

From an educational standpoint, integrating IoT into teaching and learning transforms traditional property management education into a more experiential, data-driven, and problem-based learning environment. For instance, IoT systems that monitor energy consumption or carbon output can be used in classroom simulations and digital labs to help students analyse real-time sustainability data and design energy-efficient strategies. Such activities strengthen students' understanding of environmental stewardship and sustainable property operations.

Moreover, IoT-enabled tenant-management systems, such as smart feedback portals and real-time communication platforms, can be incorporated into learning modules to train students in customer relationship management and service responsiveness, mirroring real-world professional interactions. Similarly, IoT-based IAQ monitoring tools and smart safety devices give students opportunities to explore health, comfort, and safety parameters in the built environment, reinforcing the importance of occupant well-being in property management education.

By embedding these IoT applications into teaching and learning practices, educators can bridge the gap between theory and real-world practice, fostering a new generation of property management graduates who are technologically proficient, sustainability-minded, and capable of making data-informed decisions. Therefore, the importance of IoT applications extends beyond operational efficiency; it plays a transformative role in enhancing curriculum design, practical training, and digital literacy within property management education.

6.1 REDUCE CARBON EMISSION

Climate monitoring has become one of the most pressing global concerns, with climate change affecting safety, food security, and energy systems worldwide. Information and Communication Technology (ICT), such as satellite sensing, ocean sensors, and weather radars, has become a major tool for understanding environmental impacts (Saeed et al., 2019). In the property sector, heightened awareness of carbon emissions and environmental, social, and governance (ESG) standards has driven the adoption of innovative, IoT-enabled solutions. Research indicates that property managers can reduce energy consumption by up to 25% through smart IoT systems that monitor and optimise building energy use (Ngu et al., 2016).

From a teaching and learning perspective, IoT-based carbon reduction systems can be integrated into property management curricula to enhance students' understanding of sustainable building operations and green management strategies. By analysing real-time energy data and simulating IoT-controlled systems, students can learn how digital technologies support carbon-neutral building performance and align with national sustainability goals. Such learning experiences promote environmental literacy, critical thinking, and data interpretation skills, which are essential for future property managers operating in sustainable real estate environments.

6.2 ENHANCE TENANT-MANAGEMENT RELATIONSHIPS

Improving tenant satisfaction and engagement is central to successful property management. IoT-enabled systems such as automated smart lighting, climate control, and digital feedback applications enhance communication and service quality, leading to higher tenant loyalty (Traboulsi & Knaught, 2021). For instance, automated lighting systems improve comfort, safety, and energy efficiency, while data-driven management tools allow property managers to respond quickly to tenant needs (Tupakula & Varadharajan, 2014).

In an educational context, these IoT applications can be used to teach students about digital tenant engagement and customer relationship management. By simulating IoT-based service systems, learners gain exposure to real-world management scenarios and develop interpersonal, analytical, and decision-making skills. Integrating these systems into teaching also enables students to evaluate how digital solutions affect client satisfaction and operational efficiency, making these outcomes key learning outcomes in modern property management education.

6.3 ENHANCED INDOOR AIR QUALITY (IAQ) MANAGEMENT

Many building systems produce harmful emissions that can degrade indoor air quality (IAQ) and affect occupant health. The COVID-19 pandemic underscored the importance of effective Air Quality Management (AQM) systems in maintaining safe indoor environments (Carletti et al., 2017). IoT sensors now monitor critical parameters such as CO_2 concentration, temperature, humidity, light, sound and relay data to centralised platforms for real-time analysis (Kalaithasan et al., 2018). This enables early detection of "Sick Building Syndrome" and supports proactive maintenance strategies.

For teaching and learning, IoT-based IAQ management provides hands-on learning experiences that enhance students' understanding of health, comfort, and environmental quality in building management. Educators can incorporate real-time IAQ data into coursework, allowing students to interpret environmental readings, diagnose building health issues, and propose management interventions. These activities cultivate analytical skills and sustainability awareness, preparing students to manage smart, health-conscious buildings in their future careers.

6.4 SAFETY AND SECURITY

Safety and security are critical concerns for property owners, managers, and occupants. IoT systems enhance these aspects through networked access control, surveillance cameras, motion sensors, and environmental monitoring systems, ensuring protection and operational reliability (Wolf & Serpanos, 2018). Unlike traditional systems that function in isolation, IoT-enabled security networks are interoperable and data-driven, allowing property managers to monitor and analyse multiple building functions in real time.

In teaching and learning, IoT-based safety systems can be used to train students in risk management, emergency response, and smart security system design. By engaging with simulated or real IoT security data, students learn how digital technologies contribute to proactive facility management and situational decision-making. This experiential approach reinforces practical skills, technical literacy, and critical awareness of cybersecurity in property management.

Documentation, and preparation for accreditation compliance (Marnnoi, 2024). Preparatory work, such as developing comprehensive course materials, recorded lectures, interactive assessments, detailed instructional guides, and extensive documentation portfolios required by program accreditation bodies, is mostly done by coordinators and subject-matter experts, usually lecturers and instructional designers (Rensburger et al., 2021). The program can only be run after getting accredited. After implementation, ongoing tasks include monitoring student engagement, managing virtual laboratories, continuously updating content to keep pace with rapidly evolving technologies, maintaining academic integrity in remote assessments, and preparing periodic accreditation reports. Additionally, faculty must maintain detailed records of student performance data, course delivery modifications, and continuous improvement initiatives to satisfy accreditation review cycles (MQA, 2021).

Importance of Internet of Things (IoT) Applications in Advancing Teaching and Learning in Property Management Practices	**Wilander (2018)**	**Malmodin & Bergmark (2015)**	**Mehta (2021)**	**Ngu et al. (2016)**	**Bubonya et al. (2017)**	**O'Brien (2014)**	**Traboulsi & Knaught (2021)**	**Tupakula & Varadharajan (2014)**	**Carletti et al. (2017)**	**Kalaithasan et al. (2018)**	**Wolf & Serpanos (2018)**
1. Reduce Carbon Emissions											
• Climate-related disasters cause millions of deaths	√										
• Tackling inefficient energy use			√								
• Investigating key climate-changing variables		√									
• IoT-enabled energy savings technologies help save costs				√							
2. Increase Work Productivity											
• Can be classified into absenteeism and presenteeism					√						
• The mean time to recover is much faster compared to the manual working style						√					
3. Enhance Tenant-Management Relationship											
• Having appropriate management tools								√			
• Lowering operational cost in benefitting building occupants							√				
• Comprehensive information is being shared							√				
4. Enhanced Indoor Air Quality (IAQ) Management											
• Long-period indoor needs better ventilation									√		
• Sensors detecting "Sick Building Syndrome" based on parameters									√	√	
5. Safety and Security											
• Keeps the building functionality at a higher operational level											√
• Increases the possibilities of new technological innovations used											√

Source: Researcher (2025)

Table 1: Importance of Internet of Things (IoT) Applications in Advancing Teaching and Learning in Property Management Practices on Previous Research

Table 1 highlights the importance of Internet of Things (IoT) application attributes in advancing teaching and learning in property management. Five (5) important attributes have been further reviewed from the past literature.

7. METHODOLOGY

Data were collected through a combination of semi-structured interviews and online surveys, ensuring data triangulation for greater reliability and validity.

7.1 SEMI-STRUCTURED INTERVIEWS

Preliminary interviews are conducted to obtain expert opinions and contextual understanding of IoT adoption in real property management settings. Interview questions are designed to explore how IoT practices, such as smart maintenance, energy management, and digital communication, can be used as learning tools or case studies in property management education.

Prior preparation, including question formulation and interview scheduling, ensures that the data collected provides meaningful insights into how industry practices can inform and enhance teaching methods. These respondents are selected for their direct involvement in IoT-based building management systems, making them valuable sources for identifying real-world applications that support curriculum relevance and teaching innovation in property management programs (see Table 3).

Respondent Code	Position	Company Location
E1	Property Manager	Axiata Arena, Bukit Jalil
E2	Engineer	Top Glove, Setia Alam
E3	Property Executive	Savills, Damansara

Table 3. Respondents of the Case Study

7.2 ONLINE SURVEY QUESTIONNAIRE

Following the interviews, an online survey questionnaire will be distributed to a broader sample of property managers, engineers, and executives. The questionnaire aims to measure perceptions, awareness, and attitudes toward the use of IoT and its relevance to professional learning, upskilling, and educational integration in the field.

Two types of surveys are used: a cross-sectional survey to capture the current understanding and implementation levels of IoT in property management education and practice, and a longitudinal survey to assess the perceived evolution of IoT skills and their long-term impact on learning outcomes. The survey collects both quantitative and qualitative responses to examine how IoT enhances teaching practices, such as digital simulations, real-time data learning, and smart campus initiatives.

7.3 SAMPLING TECHNIQUE AND RESPONDENT PROFILE

This study uses purposive sampling, specifically homogeneous purposive sampling, to ensure participants share characteristics relevant to the study—namely, professionals and users of mixed-use, commercial, and industrial buildings who are exposed to IoT applications in their work.

A total of 382 respondents were targeted, representing diverse roles within the property management and engineering sectors. Out of these, 306 valid responses were collected, representing an 80% response rate. This high participation rate ensures the data collected is representative and reliable for analysis. Including industry practitioners who actively engage with IoT technologies provides critical insights into how industry experiences can be transformed into teaching content and learning simulations in academic programs.

7.4 DATA ANALYSIS

The data from the surveys and interviews were analysed using a mixed-method interpretive approach. Qualitative data from interviews has been analysed thematically to identify patterns in respondents' experiences with IoT systems and their educational implications. Quantitative data from surveys processed using descriptive and inferential statistical methods to determine the level of awareness, perceived benefits, and readiness for IoT integration in property management learning.

Through this analysis, the study aims to link IoT implementation outcomes such as energy efficiency, tenant engagement, and safety enhancement with their pedagogical applications, such as simulation-based learning, case-based instruction, and digital skill development.

In summary, the chosen research methodology combines qualitative and quantitative techniques to explore both the operational importance of IoT in property management and its educational potential in advancing teaching and learning. By aligning academic inquiry with real-world practices, this study not only identifies the current impact of IoT but also proposes how these technologies can shape the future curriculum design, experiential learning, and professional competencies of property management students.

8. FINDINGS AND DISCUSSION

This section presents and discusses the study's findings on the importance of IoT applications in advancing teaching and learning in property management. The results are derived from interviews and survey analyses, emphasising how IoT-related innovations not only transform operational property management but also serve as catalysts for educational development, digital skill enhancement, and experiential learning in property management education.

8.1 ATTRIBUTES OF IOT APPLICATIONS IN PROPERTY MANAGEMENT PRACTICES IN MALAYSIA

The findings reveal three key attributes of IoT applications that are increasingly integrated into Malaysian property management practices: space utilisation and data analytics, cloud-based property maintenance, and energy control and management. These attributes are crucial not only for improving operational performance but also for shaping teaching and learning curricula that reflect real-world digital transformation.

(a) Space Utilisation and Data Analytics

Respondents emphasised inefficiencies in traditional space management, describing them as time-consuming, non-computable, and non-flexible. Manual tasks, such as on-site assessment, consumed excessive time and resources. IoT-based solutions, through real-time data analytics, automate these repetitive tasks and enable systematic data collection (e.g., occupancy rates, space optimisation).

For teaching and learning, this highlights the need to integrate IoT-driven spatial analytics software into property management education. Students can learn how to interpret real-time data for decision-making, fostering analytical and problem-solving skills critical in managing smart buildings. By simulating real IoT dashboards or digital twins in classrooms, students can gain practical, data-driven experience in property management.

(b) Cloud-Based Property Maintenance

Respondents further identified cloud-based systems, particularly for HVAC and lighting, as transformative in streamlining operations. IoT-enabled platforms centralise data, enhancing coordination and reducing Mean Time to Recover (MTTR).

For educators, this finding provides strong justification to incorporate cloud-based facility management modules into coursework. Students should be exposed to remote monitoring tools, mobile maintenance dashboards, and centralised digital record systems, enhancing their digital literacy and readiness for IoT-integrated property environments. This not only bridges academic learning with professional practice but also promotes adaptive learning using real-world technologies.

(c) Energy Control and Management

The study also found that Building Energy Management Systems (BEMS) enable real-time optimisation of energy usage, promoting sustainability and efficiency. Respondents associated these systems with reduced operational costs and improved environmental performance.

From a pedagogical perspective, BEMS represents an essential case study for sustainability education. Incorporating BEMS simulations into property management courses would allow students to explore carbon footprint monitoring, real-time energy tracking, and green-building certifications, aligning classroom learning with Malaysia's sustainability agenda and SDG 11 (Sustainable Cities and Communities).

8.2 AWARENESS AND COMPREHENSION OF IOT AND PROPERTY MANAGEMENT PRACTICES

Table 4 shows that the majority of respondents demonstrated strong awareness and understanding of both IoT and Property Management Practices (PMP), with 62.4% extremely aware of IoT and 64.4% extremely aware of PMP. Over 50% of respondents rated their comprehension as excellent.

Variable	Scale	Frequency	Percentage
Are you familiar with the term Internet of Things (IoT)?	Not Aware	24	7.8
	Slightly Aware	21	6.9
	Moderately Aware	70	22.9
	Extremely Aware	191	62.4
Are you familiar with the term Property Management Practices (PMP)?	Not Aware	14	4.6
	Slightly Aware	26	8.5
	Moderately Aware	69	22.5
	Extremely Aware	197	64.4
How would you rate your comprehension of the term Internet of Things (IoT)?	Weak	18	5.9
	Moderate	42	13.7
	Good	88	28.8
	Excellent	158	51.6
How would you rate your comprehension of the term Property Management Practices (PMP)?	Weak	16	5.2
	Moderate	38	12.4
	Good	87	28.4
	Excellent	165	53.9

Source: Researcher (2025)

Table 4. Awareness and Comprehension Based on Frequency

This finding underscores the growing familiarity of industry practitioners with digital tools and smart technologies. In the context of teaching and learning, such awareness signals a readiness among property professionals to participate in IoT-integrated education and training programs. Universities and training institutions can leverage this readiness to introduce IoT-based learning modules, augmented reality simulations, and digital competency workshops, ensuring that students and practitioners develop relevant skills for Industry 4.0.

8.3 THE IMPORTANCE OF IOT ATTRIBUTES IN ADVANCING TEACHING AND LEARNING IN PROPERTY MANAGEMENT

Semi-structured interviews identified several key attributes of IoT that contribute to both property management efficiency and educational enhancement. These include carbon emission reduction, increased work productivity, improved tenant-management relationships, enhanced indoor air quality, and strengthened safety and security (refer to Table 5).

Attributes	Results
Reduce carbon emission	• IoT-enabled smart devices reduce energy use by up to 25%, supporting carbon-neutral developments and green education frameworks.
Increase work productivity	• IoT facilitates Machine-to-Machine (M2M) communication, reducing response times and automating workflows — relevant for teaching digital facility management.
Enhancement of the tenant-management relationship	• Apps like VYROX (AUTOSERVA) strengthen communication; integrating such case studies in teaching develops student understanding of digital customer engagement.
Improvement of Indoor Air Quality (IAQ)	• IoT-based IAQ management promotes occupant health; educators can use these systems for experiential learning in sustainable building design.
Safety and security	• IoT interoperability (e.g., sensors, access control) provides rich datasets for student analysis in smart property management labs.

Source: Researcher (2025)

Table 5. Response of the Respondents based on Attributes of Internet of Things (IoT) Applications in Property Management Practices in Malaysia

From an educational standpoint, these findings demonstrate IoT's dual role as both a professional tool and a pedagogical instrument. For example, IoT-based platforms can be introduced into classroom environments to simulate energy monitoring, predictive maintenance, and security analytics, thus fostering active learning, digital literacy, and problem-solving competencies among property management students.

8.4 CORRELATION BETWEEN IOT ATTRIBUTES AND PROPERTY MANAGEMENT ASPECTS

Spearman's correlation analysis revealed positive correlations between IoT attributes and property management outcomes, validating the transformative role of IoT in optimising workflows, improving energy efficiency, and enhancing safety. Notably, Space Utilisation Analytics (Attribute 1) has shown moderate correlation (0.319–0.369) with health, well-being, and reduced carbon footprint as key themes for sustainability education. Cloud-Based Maintenance (Attribute 2) has displayed a strong correlation (0.411–0.482) with process visibility and workflow transformation, which is valuable for teaching smart operational strategies. Energy Control and Management (Attribute 3) shows a strong correlation (0.432) with network optimisation and user comfort, providing practical examples for student energy analytics projects. These findings reinforce that IoT-based property management practices can serve as real-world learning models, enabling students to engage in evidence-based learning, problem-solving, and data-driven decision-making.

Spearman's ρ	Correlation Coefficient	Correlation of IoT Attributes and Aspects of PMP	Sig. (2-tailed)	Significance of IoT Attributes and PMP
1. Space Utilisation Analytics				
• Increase Work Productivity	0.285	Weak	0.000	Significant
• Reduce Human Error	0.132	Weak	0.021	Significant
• Reduce Operational Cost	0.234	Weak	0.001	Significant
• Enhance Health and Well-Being	0.369	Moderate	0.001	Significant
• Reduce Impact on Carbon Footprint	0.319	Moderate	0.001	Significant
• Performance Rating	0.331	Moderate	0.001	Significant
2. Cloud-Based Maintenance				
• Response Time to Recover	0.277	Weak	0.001	Significant
• Increase Security	0.283	Weak	0.041	Significant
• Improve Management Workflow	0.325	Moderate	0.001	Significant
• Streamlining Property Maintenance	0.411	Strong	0.001	Significant
• Enhance the Overall Transparency	0.482	Strong	0.001	Significant
• Performance Rating	0.434	Strong	0.001	Significant
3. Energy Control and Management				
• Reduce Operational Cost	0.169	Weak	0.003	Significant
• Total Optimisation of Energy Networks	0.223	Weak	0.001	Significant
• Enhance Demand-Based Pricing Models	0.357	Moderate	0.001	Significant
• Increase Comfort of Building Occupant	0.359	Moderate	0.001	Significant
• Data Traffic Lowers the Delay and Networking	0.432	Strong	0.003	Significant
• Performance Rating	0.267	Weak	0.001	Significant
4. Technological Innovation				
• Increase Efficiency of Building Performance	0.125	Weak	0.028	Significant
• Increase Work-Efficiency	0.208	Weak	0.001	Significant
• Improve Flow of Communication	0.388	Moderate	0.000	Significant
• Increase Comfort of Building Occupant	0.351	Moderate	0.000	Significant
• Streamlining Building Operations	0.394	Moderate	0.001	Significant
• Performance Rating	0.337	Moderate	0.001	Significant
5. Real-Time Communication				
• Enhance Tenant-Management Relationship	0.125	Weak	0.028	Significant
• Increase Return on Investment (ROI)	0.208	Weak	0.001	Significant
• Increase Work Productivity of the Management Team	0.388	Moderate	0.001	Significant
• Increase Comfort of Building Occupant	0.351	Moderate	0.001	Significant
• Performance Rating	0.337	Moderate	0.001	Significant

Table 6. Spearman's Correlation between Attributes of IoT and Different Aspects of PMP

9. CONCLUSION

In conclusion, the findings confirm that IoT applications provide significant benefits for both property management and education. The integration of IoT in property management practices promotes operational excellence, sustainability, and data transparency—while simultaneously advancing teaching and learning outcomes by: Enabling practical, hands-on learning using live IoT data and simulation tools; Strengthening digital and analytical competencies among learners; Fostering sustainability consciousness through IoT-based green building case studies; Promoting industry-academia collaboration in digital property management innovation. Thus, IoT serves as both a technological enabler and an educational catalyst, bridging the gap between classroom learning and professional application. The study underscores that advancing teaching and learning in property management requires embedding IoT-driven experiential learning, data literacy, and sustainability awareness into academic and professional training frameworks.

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12. AUTHORS' CONTRIBUTION

Siti Hasniza Rosman conceptualised the study, designed the methodology, supervised the research process, and led the project administration and funding acquisition. Siti Hasniza Rosman and Suhana Ismail conducted the investigation and collected the data. Siti Hasniza Rosman performed the formal analysis and prepared the original draft of the manuscript. Suhana Ismail, Rohayu Ab Majid, and Emma Marinie Ahmad Zawawi contributed to data interpretation and validation. Rohayu Ab Majid and Emma Marinie Ahmad Zawawi reviewed and edited the manuscript and contributed to the visualisation. All authors have read and agreed to the published version of the manuscript.

13. CONFLICT OF INTEREST DECLARATION

We certify that the article is the authors' and co-authors' original work. 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 attest that all authors have contributed significantly to the work, the validity and legitimacy of the data, and the interpretation of the data for submission to IJELHE.

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A Framework for Experiential Learning: Using MOOC to Strengthen Guidance in the Food Product Innovation Project

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Abstract: *Agro-based Food Handling and Processing is a fundamental course in the Diploma in Agropreneurship (AT113), equipping students with food handling and processing and entrepreneurial skills. One of the key assessments requires students to develop a food product innovation project. However, students often struggle to fully develop and complete assessments aligned with academic and industry needs due to inconsistent guidance, time constraints, limited documentation, and a lack of student initiative. To address these challenges, this paper explores the integration of a progressive guidance and task framework of the food product innovation project into the Massive Open Online Course (MOOC) AGB296 Agro-based Food Handling and Processing course through the UFUTURE platform. The framework's structure aligns with the course topics (introduction, harvesting, post-harvest handling, food preservation, processing techniques, packaging, and branding), allowing students to apply theoretical knowledge and hands-on skills in line with Kolb's Experiential Learning Cycle. The progressive framework consists of five key stages: S1: Product Idea Development; S2: Raw Material Exploration; S3: Handling and Processing Activities; S4: Product Features, Uniqueness, and SDG Alignment; and S5: Packaging and Marketing Strategies. Each stage is supported with clear video guidelines, progress-based activities, and a* *reflective feedback mechanism that facilitates continuous interaction between students and the lecturer. The MOOC platform provides structured guidance, flexibility, and equitable access to feedback, offering a more effective and engaging alternative to traditional classroom assessment. This approach enhances the quality of student learning and innovation by mirroring real-world product development processes, thereby preparing students to contribute meaningfully to the advancement of the food industry and agropreneurial development.*

Keywords: *Assessment, MOOC, effective, agro-based, innovation*

1. INTRODUCTION

Agropreneurship has gained significant attention as a key driver for enhancing agricultural productivity, sustainability, and economic viability. The agricultural and agro-based sectors are rapidly evolving, requiring future agropreneurs to acquire both technical and entrepreneurial competencies to remain competitive and adaptive (Schoneveld, 2022; Pan et al., 2024; Gadanakis, 2024). Beyond mastering agricultural practices, students must develop skills to innovate, differentiate, and communicate their product ideas effectively to meet industry and market demands (Higgins et al., 2018; Kamalrulzaman et al., 2021; Bodescu et al., 2024; Novita, 2025). In the agro-food industry, these competencies are particularly vital, as innovation involves transforming raw materials into marketable, value-added products aligned with sustainability goals. Developing such skills empowers future agropreneurs to create innovative, value-added food products, reinforce food security, support sustainable practices, and drive rural economic growth through agro-based food handling and processing initiatives.

Massive Open Online Courses (MOOCs) have emerged as a dynamic and inclusive platform for experiential learning, offering flexibility and accessibility in higher education (Wang & Zhu, 2019; Gomez-Zermeno, 2020). MOOCs promote interactive learning environments that encourage self-paced exploration, collaboration, and continuous feedback (Liyanagunawardena, 2015). These platforms have become essential for skills training due to their accessibility and scalability, particularly in underrepresented fields like agriculture. In agricultural education, MOOCs have been instrumental in bridging the gap between theoretical understanding and practical application. Their effectiveness for applied learning depends on course design elements such as active learning activities, instructor and peer interaction, clear formative feedback, and opportunities for reflection and practice (Dinh et al., 2022; Alturkistani, 2018). The integration of project-based and reflective components into the MOOC platform fosters active learning and higher-order skill development, enhancing learners' ability to apply theory in a real-world context (Daalhuizen & Schoormans, 2018; Wang & Zhu, 2019).

The AGB296 Agro-based Food Handling and Processing course is a fundamental component of the Diploma in Agropreneurship program. This course plays an important role in bridging agricultural knowledge with agropreneurial competencies, providing students with a fundamental understanding of food handling, processing, and product innovation. The course equips students with essential technical and soft skills required in the agro-food industry (Gaspar et al., 2015). Integrating the food product innovation project into this course allows students to apply theoretical knowledge to real-world scenarios, enhancing their creativity, problem-solving, and innovation skills. Moreover, hands-on experience exposes students to market trends, consumer preferences and sustainable technologies, enabling them to create unique, competitive, and value-added agro-based food products.

However, traditional classroom approaches have focused more on theoretical instruction, leaving a gap in providing well-structured and continuous guidance for developing agro-based food products. Students often struggle to translate theoretical knowledge into practical product innovation due to time constraints, inconsistent feedback, and limited opportunities for consultation. To address these gaps, integrating an agriculture-focused MOOC provides a structured, flexible, and accessible learning platform that guides students through each stage of product development. The AGB296 Agro-food Handling and Processing MOOC exemplifies innovation by embedding instructional videos, progress-based activities, and reflective feedback mechanisms into its structure. This approach facilitates continuous monitoring, provides equitable access to feedback, and enables self-paced learning, enabling students to conceptualise, process, and commercialise agro-based food products effectively. Thus, MOOCs serve as a transformative tool in advancing practical skill acquisition and entrepreneurial readiness in agroprenerurship education.

2. PROBLEM STATEMENT

Current teaching approaches for food product innovation assignments rely heavily on theoretical instruction with traditional in-class presentation and verbal feedback. This approach restricts feedback documentation, limits students' reflection and often results in inconsistent guidance across groups. Moreover, lecturers may struggle to provide sufficient attention and feedback to all groups due to limited consultation time. At the same time, some students may show little initiative in seeking clarification or feedback from the lecturer. These constraints contribute to students' low confidence in translating theoretical knowledge into a viable food product. Furthermore, without structures and accessible guidance, certain student groups struggle to complete the assignment effectively.

To address these issues, embedding Food Product Innovation Project Progress Guidelines into the MOOC platform offers a digital solution that ensures structured, traceable, and equitable access to learning resources, guidance and feedback.

3. FRAMEWORK DEVELOPMENT

MOOC AGB296 was first developed in 2024 and follows a course syllabus covering five main topics. The framework for the Food Product Innovation Project Progress Guidelines is organised into five progressive tasks, embedded within the five main topics of the AGB296 course (Table 1 and Figure 1). Each progress guideline consists of a lecturer-prepared instructional video (Figure 2), a structured, progress-based activity (Figure 3), a student feedback form (Figure 4), and a lecturer feedback form (Figure 5), designed to promote experiential and reflective learning. Depending on the integrated progress-based task, students are required to demonstrate their progress through in-class presentations, video submissions, or infographic posters (Figure 6). Moreover, the progress-based activity is included as one of the components during the class sessions, allowing students to engage in guided learning while receiving immediate feedback and support from peers and the lecturer. The framework also enables lecturers to provide structured and formative feedback directly within each progress task. Feedback is provided through a digital rubric for grading and documentation, and through a discussion forum linked to each task for formative dialogue. The structured approach ensures clarity, consistency and continuity across all learning stages. The framework designation supports Kolb's Experiential Learning Cycle, which emphasises learning as a continuous process involving experience, reflection, conceptualisation, and experimentation (Figure 7). The framework's continuous cycle encourages continuous learning and innovation, bridging classroom learning with real-world agropreneurship practice.

Course Topics	**Integrated Progress Guidelines**	**Objective**
1. Introduction to Agro-based Food Handling and Processing	Stage 1 (S1): Idea Product Proposal	To guide students in identifying problem statements using the 5W1H (What, Who, When, Where, Why, and How) concepts and propose ideas according to the given theme.
2. Agro-based Harvesting	Stage 2 (S2): Raw Material Selection	To guide students in analysing the main raw material function, health benefits, limitations in handling and processing, and sustainability.
3. Post-harvest Handling	Stage 3 (S3): Handling and Processing	To guide students in describing the processing flow, safety and processing method.
4. Food Preservation and Processing	Stage 4 (S4): Product Features, Value/ Benefits, Uniqueness and SDG Alignment	To guide students in identifying features, benefits, uniqueness and SDG contribution.
5. Packaging, Storage & Branding	Stage 5 (S5): Packaging, Branding, 4Ps and Commercialisation Potential	To guide students in selecting suitable packaging, justify the choice, outline the brand and logo story, 4Ps engagement and commercialisation potential.

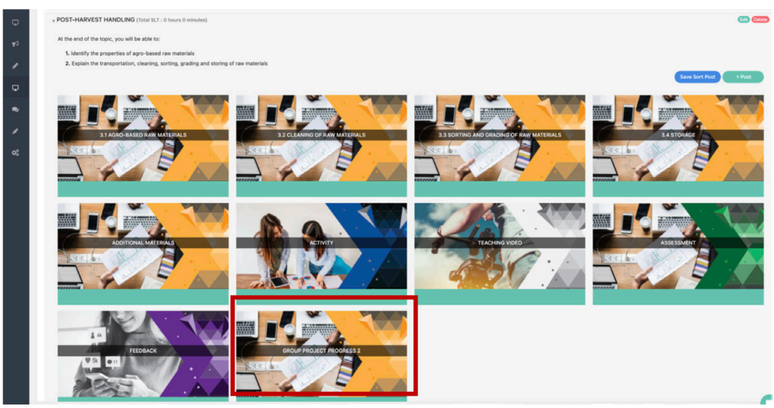

Figure 1. The Food Product Innovation Project Progress Guidelines are embedded into the main topics of the AGB296 course on MOOC.

Figure 2. An original instructional video by the author on food product innovation project guidelines via MOOC.

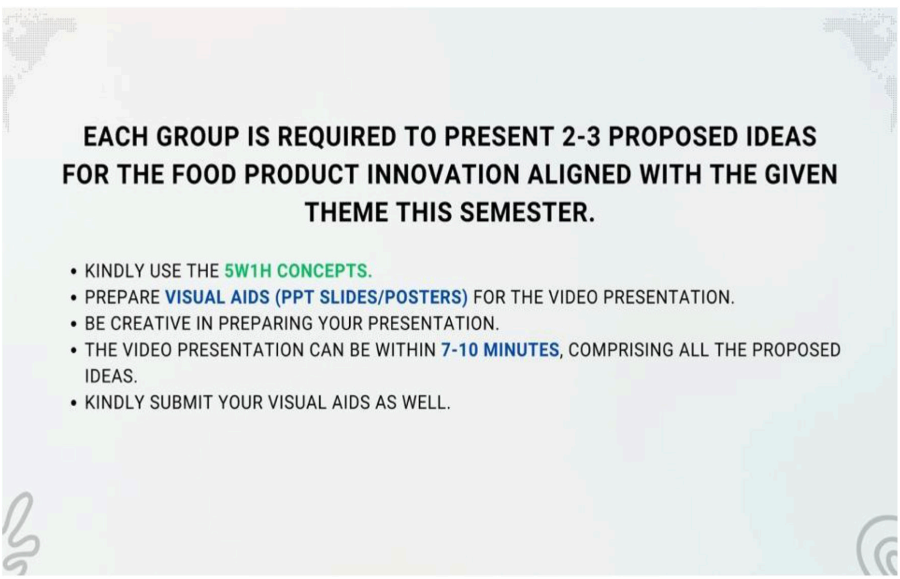

Figure 3. Example of embedded progress-based activity for the Food Product Innovation Project Progress.

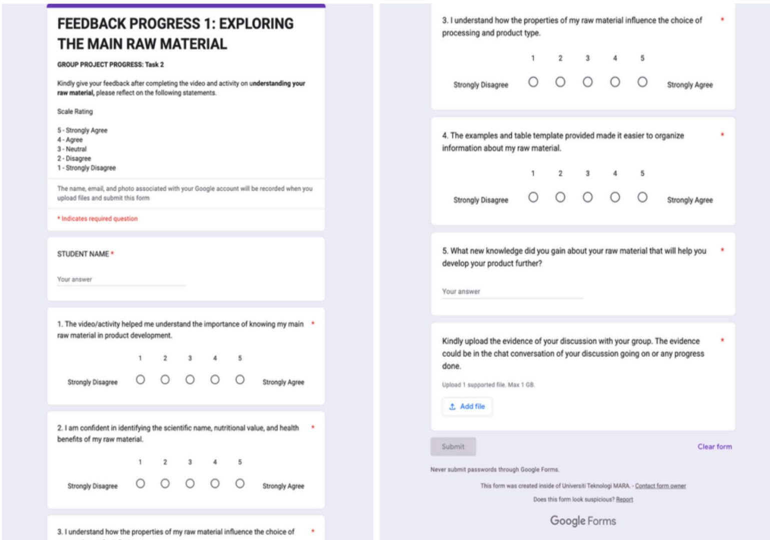

Figure 4. A Google Form to collect students' feedback on the progress guidelines.

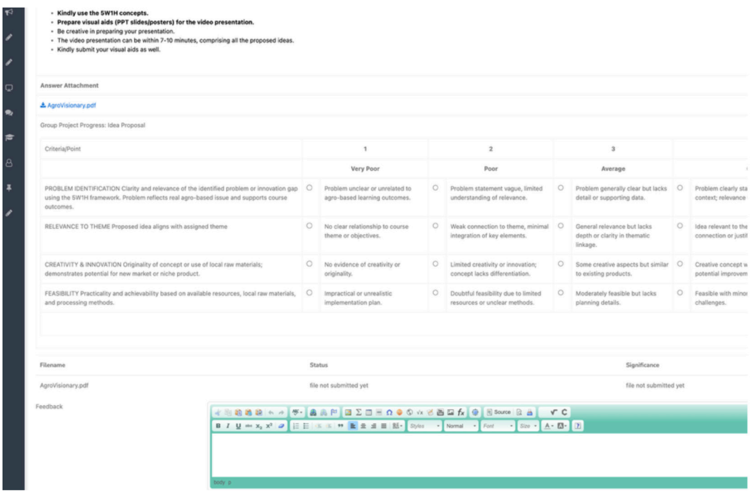

Figure 5. Lecturer feedback feature within the MOOC-integrated framework for the Food Product Innovation Progress.

The integrated progress guidelines framework promotes experiential learning in the AGB296 Agro-based Food Handling and Processing course by ensuring learning occurs through doing, reflecting, and improving. Each progress stage is supported by structured video guidelines, progress-based activities, and a feedback mechanism that allows students to apply theoretical concepts through guided, hands-on learning. Moreover, these components aim to guide students systematically through the stages of food product development while encouraging continuous improvement. Progress-based activities are embedded in the course lesson plan throughout the semester, helping students clearly understand the timeline and expectations for each stage of product development. With a structured schedule, students can plan, prepare, and complete their project milestones, meeting the submission date. Furthermore, the use of digital tools, particularly infographic posters and video presentations, promotes students' creativity and communication competencies by encouraging the articulation of ideas and project outcomes through visually engaging and innovative formats. The dual feedback system, which delivers lecturers' feedback on students' progress, allows continuous monitoring of student progress, ensures transparency and accessibility, and enables students to revisit feedback at their own pace and align improvements with subsequent tasks.

Through the MOOC platform, students will have the flexibility to learn at their own pace. At the same time, the lecturer can systematically monitor progress, provide continuous feedback, and ensure equitable access to guidance across all groups. The framework can promote creativity, problem-solving, and innovation in students by simulating real-world food product development processes aligned with industry practices. These also foster entrepreneurial skills and agropreneurial competencies, aligning with national goals to develop agropreneurs who can transform local produce into innovative commercial products and support sustainability. Overall, the framework provides a structured, transparent, and flexible mechanism to strengthen the quality of student guidance, reflection, and innovation in the agro-based food course. The MOOC platform may serve as an experiential learning tool for agropreneurship education. Future implementation will focus on evaluating its effectiveness in guiding, improving the quality of food product innovation, and enhancing students' learning experience.

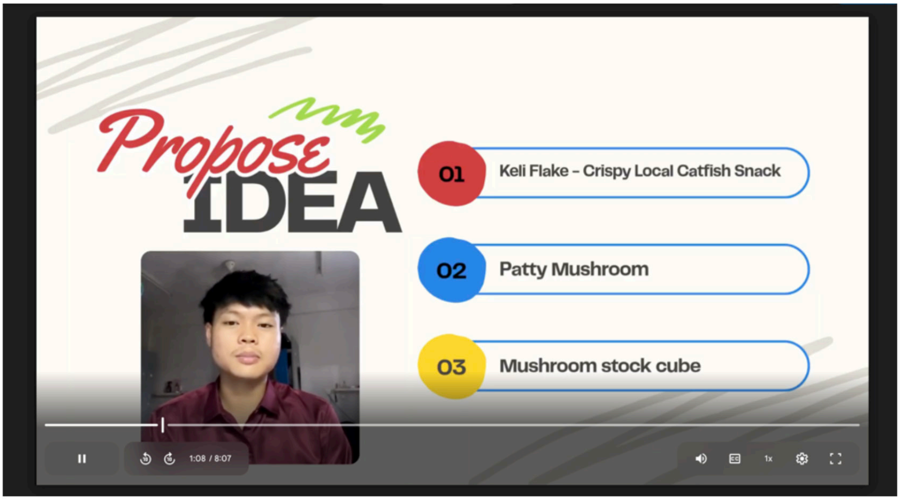

Figure 6. Example of a task completed and presented in video form by students for the Food Product Innovation Project Progress.

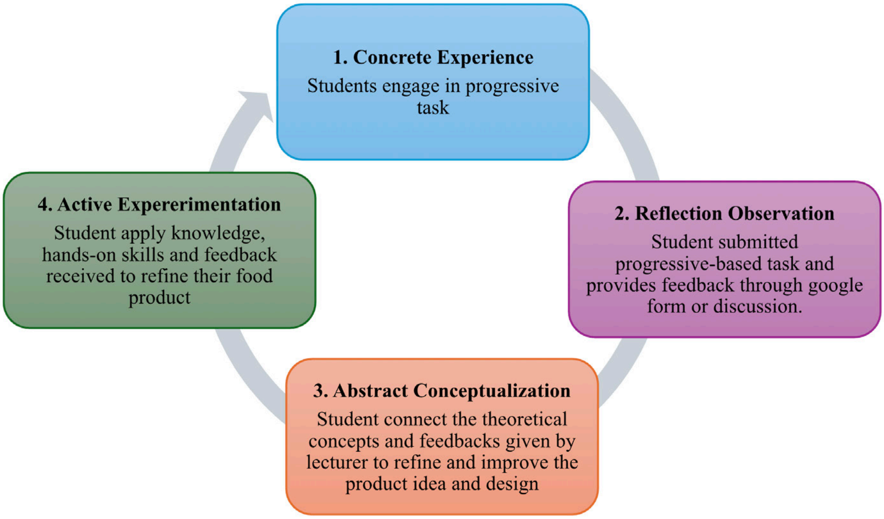

Figure 7. Aligning the framework design with Kolb's Experiential Learning Cycle.

4. CONCLUSION

This paper presents a framework for integrating Food Product Innovation Project Guidelines into the MOOC platform to support experiential learning in agro-based food innovation. The approach offers a practical solution to enhance structured guidance to students, reflective and continuous learning, and industry alignment. The guidelines not only help students complete their project assignments but also empower them to develop innovative, sustainable, and marketable food products while promoting independent learning. Future work will include implementing and evaluating the framework in real-world settings. Adopting this model in other vocational or entrepreneurial programs is recommended to support innovation-driven learning through digital platforms.

5. ACKNOWLEDGEMENT

Special thanks to the Diploma in Agropreneurship students for their valuable feedback, which has greatly supported the continuous improvement of teaching and learning strategies in AGB296 Agro-based Food Handling and Processing.

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7. AUTHORS' CONTRIBUTION

The framework was conceptualised by Sinong, G. F., who led its development. The initial draft of the manuscript was written by Sinong, G. F., who contributed to subsequent revisions, critically reviewed the content, and approved the final manuscript for submission.

8. CONFLICTS OF INTEREST DECLARATION

I certify that the article is the authors' original work. The article has not received prior publication and is not under consideration for publication elsewhere. This manuscript has not been submitted for publication, nor has it been published in whole or in part elsewhere. I testify that the author has contributed significantly to the work submitted to IJELHE.

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Enhancing Drone Education in Malaysia: STEM and TVET Framework Perspective

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Abstract: *The integration of drone technology into education is increasingly recognised as a means to enhance Science, Technology, Engineering, and Mathematics (STEM) learning and Technical and Vocational Education and Training (TVET). Despite its potential, Malaysia faces challenges in fully integrating drones into the education system, including a lack of structured curricula, insufficient training for educators, and regulatory constraints. This study explores the integration of STEM and TVET principles into drone education and training in Malaysia, aiming to bridge the gap between technological advancements and workforce readiness. The primary objectives of this study are to analyse the current state of drone education in Malaysia, identify key implementation challenges, and develop a structured framework for integrating drone education into STEM and TVET programs. A mixed-methods research approach was employed, combining quantitative assessments, qualitative evaluations, pre- and post-assessment, and workshop-based training to measure participants' knowledge improvement and engagement. Initial findings reveal that structured drone training programs significantly enhance students' technical competencies, safety awareness, and career preparedness, but are not very effective from a regulatory compliance perspective. The Reusable Learning Object (RLO) approach has been used for the Safety and Regulations module, and it has significantly improved candidates' understanding.*

Keywords: *STEM, TVET, drone education, Reusable Learning Object (RLO), drone operation*

1. INTRODUCTION

Unmanned Aerial Vehicles (UAVs), commonly known as drones, are aircraft operated without an onboard pilot (Antony & Rodrigo, 2025). The initial stage of drone applications focused on data acquisition and reconnaissance for military intelligence, or they were used in risky missions for human-pilot aircraft (Watts et al., 2012). Recently, UAVs have been used for data collection in various research studies, driving the need to incorporate them into education. As technology has advanced, the cost of UAVs has decreased, and their use has expanded into recreation and research (Salami et al., 2014).

The use of UAVs has seen a significant surge in the Science, Technology, Engineering, and Mathematics (STEM) fields. Consequently, there is a growing necessity to incorporate UAV training into STEM education. Three distinct approaches can be adopted to introduce UAVs into educational settings: involving students in a capstone project with UAVs, integrating a UAV education module into an existing course, or creating a dedicated course solely focused on UAVs (AL – Tahir, 2015). In support of this idea, Alkaabi et al. conducted a study wherein a hands-on UAV workshop was organised for students at the United Arab Emirates University. Remarkably, this workshop led to improved teamwork, communication, and critical-thinking skills among the students. Furthermore, the study revealed that the UAV workshop effectively equipped students with real-world problem-solving capabilities (Alkaabi & Abdelgadir, 2017). In light of these findings, it is evident that UAV education has immense potential across various STEM disciplines, offering students valuable skills.

Recent studies on the drone market in Malaysia indicate that the drone industry could add RM50.71 billion to the Gross Domestic Product (GDP) and create 100,000 jobs by 2030. So far, over 200 drone technology companies have been identified in Malaysia and with the increasing demand, the number of companies (domestic players) is expected to grow exponentially. While some developed countries have successfully incorporated drone technology into STEM education, Malaysia faces challenges such as insufficient infrastructure, limited teacher training, and the absence of a structured drone-education curriculum. Additionally, stakeholders lack awareness and understanding of the potential of drones as an educational tool.

A significant concern is the risk of drone crashes due to inadequate operational skills or poor understanding of safety protocols, which can lead to financial losses, equipment damage, and safety hazards. One of the latest drone incidents that was reported was in July 2023. The accident involving an agricultural drone took place on Nomination Day in Kedah. The drone, originally used for agricultural purposes, lost control and crashed into a bystander, injuring them. This incident raises important concerns about the safety protocols for using drones in public areas, particularly when they are not intended for recreational or commercial use. It also underscores the need for stricter regulations and better training for operators to prevent such mishaps in the future (CAAM, 2023). One of Malaysia's leading drone companies, the Official DJI Service Centre, has reported that the cost of repairing drones in the country is approximately RM400,000 per month. As drones become an essential part of industries, this repair cost underscores the need for advanced technology and skilled technicians to ensure they remain functional and safe to operate. Furthermore, it emphasises the importance of developing more durable and efficient drone models to reduce long-term repair costs. Embarking on this issue, drone education needs to plan properly.

The integration of drone technology into TVET and STEM education represents a forward-thinking approach to enhance technical skills and stimulate interest in science and technology. According to Mazlan et al. (2020), TVET institutions in Malaysia have increasingly recognised the potential of incorporating drone training into their programs. The hands-on experience in drone assembly, flight operations, and data analysis equips TVET students with practical skills relevant to the drone industry. In STEM education, drone technology has been utilised to enrich learning experiences and increase student engagement. Integrating drones into STEM activities allows students to explore real-world applications, such as aerial surveys and environmental monitoring, fostering a deeper understanding of scientific concepts and enhancing problem-solving skills (Yusof et al., 2021). While the integration of drones into TVET and STEM education offers numerous benefits, it also presents challenges that need to be addressed. Limited resources for drone equipment and training can hinder the implementation of drone-based programs (Azmi et al., 2021). Ensuring that educators are well-prepared to teach drone technology effectively is also crucial, as discussed by Ng et al. (2019). Additionally, safety and ethical considerations related to drone operation must be carefully addressed to ensure responsible and legal usage.

The integration of drones into TVET and STEM education aligns with industry needs and enhances graduates' employability. According to Mohd Zaid et al. (2018), drone training in TVET equips students with technical skills in demand across sectors such as aerial surveying, agriculture, and construction. For STEM graduates, drone technology provides valuable exposure to cutting-edge applications, making them competitive in the job market, as noted by Yusof et al. (2021). The literature on TVET and STEM education with a focus on drones in Malaysia showcases the nation's dedication to developing a skilled and innovative workforce. The integration of drone technology into TVET and STEM education offers promising opportunities to enhance technical competencies and stimulate interest in science and technology. Addressing challenges related to resources, educator readiness, and safety considerations will be essential in maximising the benefits of drone-based TVET and STEM education. Overall, the incorporation of drones reflects Malaysia's commitment to nurturing a skilled workforce capable of driving economic growth and technological advancement.

As of December 1, 2021, CAAM requires all drone operators, whether individuals or organisations, to obtain a Remote Pilot Certificate of Competency (RCoC) to operate drones in Malaysia legally. This certification ensures that individuals and organisations operating drones in Malaysia possess the necessary knowledge and skills and comply with aviation safety regulations. This certification is mandatory for operating drones within Visual Line of Sight (VLOS) under specific conditions. By equipping participants with both theoretical understanding and practical expertise, the program seeks to mitigate operational risks, enhance the efficiency of drone applications, and support the development of a well-regulated drone industry in Malaysia. The Basic RCoC-B Training focuses on foundational aspects, including aviation regulations, drone flight principles, safety protocols, and hands-on flight training, enabling participants to operate drones safely within Visual Line of Sight (VLOS).

The training programs typically cover a comprehensive range of topics, including Air Law and Responsibilities: Understanding the legal framework governing drone operations, UAS/Drone Airspace Operating Principles: Navigating airspace and adhering to operational rules, Airmanship and Aviation Safety: Promoting best practices for safe flight operations, Operational Procedures: Developing standard operating procedures for various missions, Human Performance Limitations: Recognizing factors that affect pilot performance, Meteorology: Assessing weather conditions for safe drone operations, Navigation: Planning and executing precise flight paths, UAS General Knowledge: Gaining insights into drone systems and functionalities. Malaysia's drone training programs are structured to produce competent remote pilots who adhere to CAAM regulations and industry best practices. The collaboration between regulatory bodies and training institutions ensures that the country's drone operators are well-equipped to meet the growing demands of various industries, thereby advancing drone technology and its applications in Malaysia.

Malaysia has implemented several policies to promote STEM (Science, Technology, Engineering, and Mathematics) education and regulate drone operations. The Malaysian Education Blueprint 2013–2025 emphasises the integration of STEM education to prepare students for future challenges. The blueprint outlines strategies to enhance STEM teaching and learning, aiming to increase student interest and proficiency in these fields (Siti et al., 2022). Drone training in Malaysian schools represents a significant step toward aligning education with technological advancements and industry demands. While challenges like cost and regulatory hurdles exist, the benefits, including enhanced STEM education, innovation, and career readiness, make it a valuable investment in the nation's future. Malaysia's diverse landscapes and natural beauty make it an attractive destination for drone enthusiasts seeking breathtaking aerial views.

However, this growing industry also faces challenges related to safety, privacy, and regulatory compliance. The Malaysian government has been actively addressing these concerns by implementing guidelines and regulations to ensure responsible drone use. As the industry continues to expand, stakeholders are focusing on raising awareness, providing education, and promoting sustainable practices to harness the full potential of recreational drones in Malaysia. In this study, the integration of STEM education and the TVET

SKM program will be reviewed, with a focus on its suitability for creating a drone education and training framework. To achieve this, several activities will be conducted, including a pre-assessment test, on-site workshop activities, sampling, and a post-assessment, to verify the effectiveness of the workshop and the prior activities. Addressing these issues is critical to ensuring that Malaysia remains competitive globally while fostering a culture of responsible and safe drone use. This research aims to investigate these challenges and develop a comprehensive framework to effectively integrate drone technology into Malaysia's education system, with a strong emphasis on safety measures to mitigate risks and prevent operational failures.

2. METHODOLOGY

This chapter outlines the research methodology employed in this study on STEM and TVET in drone education and training in Malaysia. The objective of this research is to examine the integration of STEM (Science, Technology, Engineering, and Mathematics) and TVET (Technical and Vocational Education and Training) in drone-related education and training programs, assessing their effectiveness, challenges, and potential improvements. To achieve these objectives, a mixed-methods approach is adopted, combining both qualitative and quantitative research methods.

2.1 PRE AND POST-TEST

To provide a quantitative view to complement the study, a set of questions on the focus content was selected. With that, it was possible to compare participants' performances within the same group before and after the activity/event. The material was prepared by an engineering lecturer and a student, aiming to serve as a pre- and post-test. This set of questions is derived from the basic drone operational scope and will be created in Google Forms. This study did not cover teaching people how to fly drones (since many resources already exist), flying drones for commercial profit or business (which requires special licenses), or building and/or coding drones (since these are too heavy for recreational use). The questions focus more on safety, basic regulations, drone components, and a feedback column for users to respond. Also, the set of questions is being developed based on STEM and TVET elements, which favours basic drone operation. Before the start of the Workshop, a pre-assessment test was conducted to evaluate participants' prior knowledge, covering three key areas: drone applications, drone components, and safety and regulations.

2.2 WORKSHOPS / ACTIVITIES

A workshop named the Fundamentals of Drone Technology Workshop has been organised in line with the objective.

2.2.1 ACTIVITY 1: INTRODUCTION TO DRONE TECHNOLOGIES AND APPLICATIONS

This first activity was conducted through an engaging combination of lecture and multimedia presentation. Participants attentively followed along as a series of informative slides was displayed, accompanied by high-quality images and video. These visual elements provided a more comprehensive perspective on drones, their components, and their real-world applications. The session lasted one hour and was structured into three 20-minute modules. The first module introduced participants to drone technology, covering fundamental topics such as the definition of drones, their types, and the physics of flight. This segment provided a solid theoretical foundation, helping participants understand how drones achieve stability, manoeuvrability, and control in flight. The second module explored the practical applications of drones across various industries and introduced participants to key sectors that utilise drone technology.

2.2.2 ACTIVITY 2: UNDERSTANDING DRONE LAWS AND REGULATIONS

The second activity aimed to gather information on related drone regulations, particularly those in Malaysia. This activity aims to increase participants' understanding of the regulatory concepts involved in flying a recreational drone and to raise awareness. Activity 2 was a comprehensive 1-hour session focusing on drone laws and regulations. The session was conducted through a structured lecture and multimedia presentation, incorporating slides, images, and video to enhance participants' understanding of legal and safety aspects of drone operations. This session aimed to provide participants with crucial knowledge about responsible drone usage, legal requirements, and regulatory frameworks governing drone activities in Malaysia.

The session was divided into three 20-minute modules: Drone Safety Guidelines, Drone Laws in Malaysia & Regulatory Authorities, and Permit Applications & Licensing Requirements. By the end of the session, participants had a clear understanding of the legal, safety, and regulatory aspects of drone operation in Malaysia. The session emphasised the importance of complying with aviation laws to ensure safe and responsible drone use in both personal and professional settings. Extensive work was done for this part, which focused on analysing the videos and the UAV simulation. It consisted of a sequence of Reusable Learning Objects (RLOs) and was part of Activity 3.

2.2.3 ACTIVITY 3: REUSABLE LEARNING OBJECTS (RLO)

RLOs are defined by Valderrama et al. (2005) as "any digital resource that can be reused to support web-based learning." Documents, webpages, live or pre-recorded video or audio, or other content that can be accessed independently and combined to create an instructional lesson can be part of an RLO. The RLOs in this study include: (1) a pre-assessment online survey in Google Forms, (2) a video lecture on UAV law in Malaysia on flying a drone and a series of UAV flight videos, (3) a multiple-choice online quiz on Google Forms, and (4) a post-assessment online survey in Google Forms. The results of this activity include participants' understanding of the concepts involved, increased awareness of the importance of regulations applied to drone operations, and the educational value gained from involvement in this field. Activity 3 focused on Reusable Learning Objects (RLO) to enhance participants' understanding of drones through a structured, self-paced learning approach. This session utilised online assessments, video-based learning, and interactive quizzes to evaluate participants' knowledge before, during, and after the workshop. The activity was divided into four parts, each designed to track learning progress and reinforce key concepts effectively. The activity lasted one hour, with participants engaging in both individual and guided learning exercises.

2.3 SAMPLES, DATA COLLECTION PROCEDURES

The target population for this study consists of diploma students from various universities in Malaysia. Specifically, the sample includes first-year and second-year diploma students enrolled in various academic programs. A total of 60 students were selected as the sample size for this study. The rationale for choosing this sample size is based on practical feasibility, while ensuring sufficient representation for analysis. All selected participants have no background in drone technology. Data collection is conducted through structured surveys distributed in Google Forms to the students. The questionnaire consists of multiple-choice and Likert-scale items designed to gather information efficiently. The survey is administered online and in person to maximise participation and ensure data reliability.

3. RESULTS AND DISCUSSION

The second set assesses the effectiveness of the workshop in enhancing participants' understanding of drone technology.

3.1 ANALYSIS OF PRE AND POST-ASSESSMENT ON DRONE TECHNOLOGIES

To evaluate the effectiveness of the workshop on drone technologies, a pre- and post-assessment questionnaire was administered to participants to measure their understanding of key concepts before and after the workshop. The assessment covered multiple aspects of drone technologies, including components, applications, and safety regulations. The pre-assessment provided a baseline for assessing participants' prior knowledge, while the post-assessment measured their learning outcomes. By comparing the results, improvements in understanding and knowledge retention were analysed. This section presents a detailed comparison of the scores from both assessments, highlighting areas of significant improvement and identifying any gaps that may require further reinforcement. The categorises questions by their respective modules—Components, Application, and Safety & Regulation —to provide a clearer view of knowledge improvement across different topics. A significant increase in post-assessment scores would indicate that the workshop successfully improved participants' knowledge. In contrast, minimal improvement or decline in certain areas may highlight concepts that require further clarification or additional training.

It is important to note that the question numbers in the pre- and post-assessment are not fully synchronised. This discrepancy arises from the way some questions in the post-assessment are structured to better align with the workshop content and learning objectives. While most core concepts remained consistent, some questions were refined, merged, or slightly modified to enhance clarity and relevance. Despite these adjustments, the fundamental themes assessed in both pre- and post-assessments remain comparable. Therefore, the analysis focuses on overall trends in knowledge improvement rather than direct one-to-one comparisons between specific question numbers.

3.2.1 PERFORMANCE ANALYSIS OF THE COMPONENTS MODULE

The Components Module aimed to assess participants' understanding of fundamental drone components, including flight controllers, GPS functionality, control methods, and video transmission systems. The performance analysis reveals notable improvements across all assessed areas, indicating that the workshop effectively reinforced key concepts and addressed prior misconceptions. The result is shown in Figure 1. The Flight Controller Function pre-assessment results indicate that only 32% of participants correctly identified the function of a drone's flight controller. A large proportion of responses incorrectly associated stability and movement control with propellers or flight controllers, and GPS modules with GPS modules, suggesting a gap in understanding of this component's primary role. However, following the workshop, the post-assessment results show a 47% increase in correct responses, with 79% of participants accurately recognising that the flight controller regulates the drone's stability and movement. This significant improvement suggests that, prior to the workshop, participants may have been more familiar with visible drone components, such as propellers, but less aware of the internal control mechanisms. The workshop's content, likely including explanations and demonstrations of flight control systems, played a crucial role in clarifying this concept.

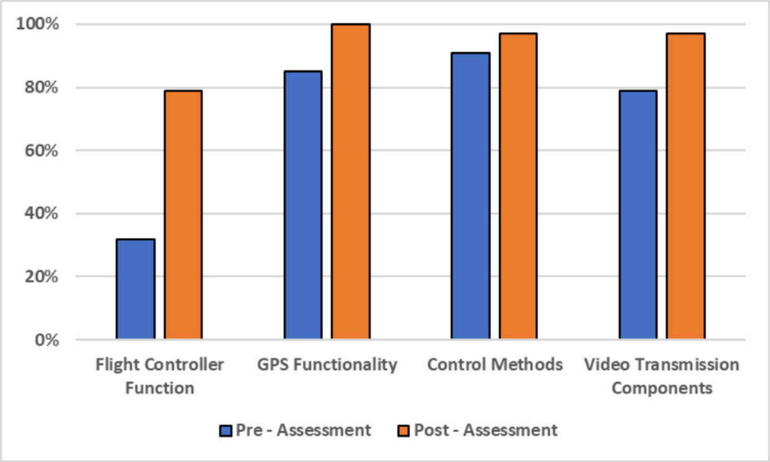

Figure 1. Overview of the Component Module Assessment

In contrast to the flight controller question, participants' understanding of GPS functionality was relatively high even before the workshop, with 85% answering correctly in the pre-assessment. The post-assessment results show a significant improvement to 100%, a 15% increase, indicating that participants already possessed a strong foundational knowledge in this area. This suggests that participants were either previously exposed to or inherently understood GPS technology and its role in navigation and positioning. While the workshop reinforced this knowledge, future sessions may consider incorporating more advanced GPS topics, such as RTK corrections, GPS-denied navigation, or integration with other positioning systems. The question on Control Method, assessing participants' understanding of how drones are controlled, also showed a notable increase in performance. Before the workshop, 91% of participants correctly identified a remote controller or a smartphone app as the standard method for operating a drone. This figure rose to 97% in the post-assessment, representing a 6% improvement. This suggests that the workshop was successful in reducing uncertainty about drone control methods. Likely, practical demonstrations of remote controllers and mobile applications, along with their functionalities, contributed to this improvement. Hands-on experience may have reinforced theoretical knowledge, ensuring that all participants grasped the concept.

A key aspect of drone operation involves video transmission, which requires both a camera and a video transmitter. In the pre-assessment, 79% of participants correctly identified these as the essential components for transmitting live video from a drone. Post-assessment results show 97% accuracy, reflecting an 18% increase in correct responses. This improvement indicates that while some participants may have had a general understanding of video transmission, the workshop played a crucial role in clarifying the specific hardware requirements involved. The significant gain suggests that discussions on payload systems, data transmission, and onboard video processing effectively improved participants' understanding of the topic.

The results of the Components Module assessment suggest that the workshop was highly effective in enhancing participants' knowledge. The most significant improvement was in understanding the flight controller's function, an area where participants initially struggled. Conversely, knowledge of GPS functionality showed only minor gains, likely due to participants' prior familiarity with the topic. The increase in correct responses for drone control methods and video transmission components further demonstrates the workshop's effectiveness in addressing key knowledge gaps. These findings highlight the importance of interactive learning methods, particularly hands-on demonstrations, in reinforcing conceptual understanding.

3.2.2 PERFORMANCE ANALYSIS OF THE APPLICATIONS MODULE

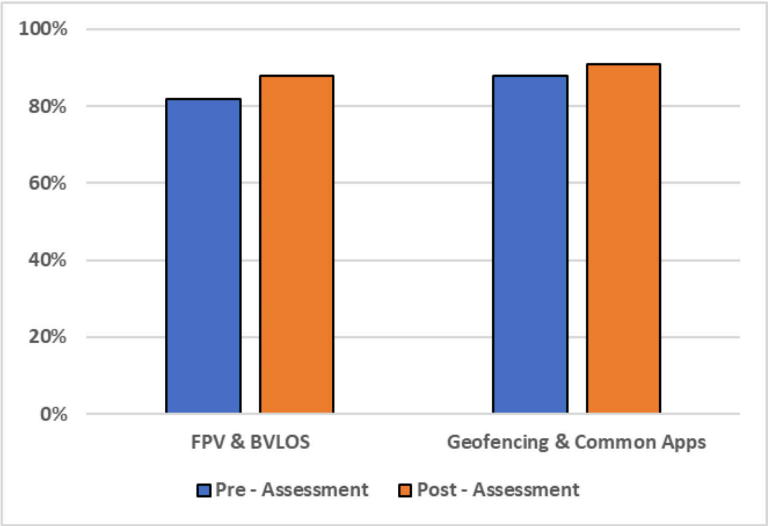

Figure 2. Overview of the Application Module Assessment

The Application Module assessed participants' understanding of key drone applications, including First-Person View (FPV), Beyond Visual Line of Sight (BVLOS) operations, geofencing, and common drone uses. The performance trends shown in Figure 2 indicate significant improvements in some areas. A direct comparison between FPV and BVLS reveals a 6% increase in correct responses, from 82% to 88%. This increase suggests that while participants grasped FPV operation well, they had greater difficulty distinguishing BVLOS from other flight modes, such as autonomous flight and manual control. The confusion may stem from the overlap between FPV and BVLOS, as FPV can be used for BVLOS operations in certain cases. The post-assessment results indicate that additional emphasis on the distinction between FPV-based piloting and regulatory restrictions of BVLOS flights would be beneficial in future training sessions. Similarly, a 3% increase in accuracy is observed between

Geofencing and Common Drone applications. This slight increment suggests that while participants understood the technical function of geofencing, they may have found it more challenging to categorise practical drone applications correctly. Strengthening the link between geofencing and real-world scenarios, for example, through interactive case studies or hands-on simulations, could help improve retention in future training programs. While participants retained knowledge of drone safety features, they may have experienced some confusion when distinguishing among various practical applications. One possible explanation is that the workshop emphasised safety and operational aspects, leading participants to be more confident in technical features (e.g., flight restrictions and automation) than in real-world applications such as agriculture, environmental monitoring, or traffic observation.

3.2.3 PERFORMANCE ANALYSIS OF THE SAFETY AND REGULATIONS MODULE

The Safety and Regulations Module aimed to strengthen participants' understanding of drone safety protocols and regulatory compliance. The post-assessment results highlight notable declines across all areas, indicating that reinforcement is needed. A direct comparison of pre- and post-assessment scores for specific question pairings provides deeper insight into learning outcomes, as shown in Figure 3. For Airspace Safety, a significant decline was observed in the question on recommended action when encountering a manned aircraft, with scores dropping from 94% in the pre-assessment to 50% in the post-assessment. This suggests a gap in knowledge retention or in the practical application of airspace safety protocols. The training should incorporate real-world scenario-based exercises and simulation-based decision-making drills to ensure that participants can effectively recall and apply this knowledge under real flight conditions.

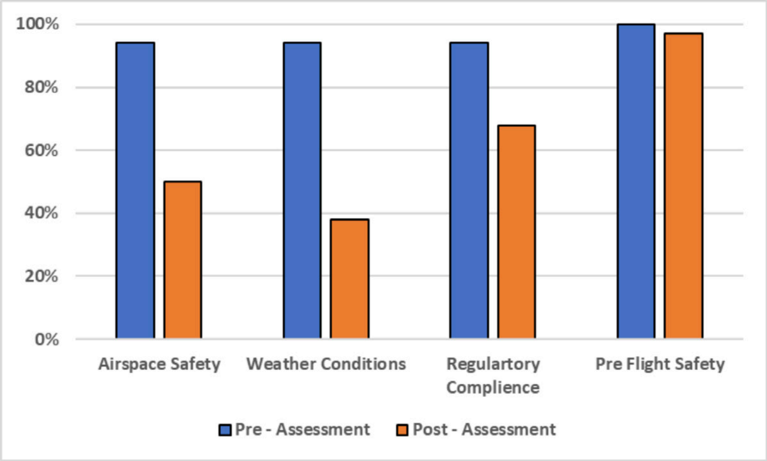

Figure 3. Overview of the Safety and Regulations Module Assessment

A major reduction was observed in the assessment of safe weather conditions for drone operations, with the score decreasing from 94% in the pre-assessment to 38% in the post-assessment. A moderate reduction was observed in participants' retention of legal altitude limits for drone operations, as assessed through Regulatory Compliance, with scores decreasing from 94% to 68%. While this still reflects a relatively strong understanding of regulations, the decline suggests that some participants may struggle with retaining specific legal requirements over time. Given the dynamic nature of drone regulations, ongoing refresher assessments, interactive regulatory case studies, and real-world application exercises could help reinforce these legal constraints and ensure compliance awareness remains high. For Pre-Flight Safety, a slight decrease was observed in responses to pre-flight safety procedures, with the score declining from 100% to 97%. While the change is minimal, it indicates that even well-understood concepts can experience minor lapses in retention. To maintain near-perfect performance in this area, training should continue to emphasise routine pre-flight checklists and integrate mandatory hands-on practice during flight exercises to build strong procedural habits.

3.3 ANALYSIS OF THE RLO APPROACHED

Since the initial achievement of the Safety and Regulations Module was not very convincing, an RLO approach has been implemented to improve participants' understanding. A multiple-choice quiz was administered covering all areas of the Safety and Regulations module. The results indicate that students demonstrated a strong understanding of the "Pre-Flight" module, with all three questions achieving high accuracy scores (91%-100%). This suggests that the instructional videos for this module effectively conveyed the necessary information. Conversely, the "Safety & Regulation" module showed more variability in performance. While most questions had high correct-answer percentages (above 90%), assessments of Uninvolved Public and GPS Signal recorded significantly lower scores (41% and 38%, respectively). These results suggest that certain concepts in this module may require further clarification or additional instructional support. Further analysis of responses to these assessments indicates potential misunderstandings about drone operational safety. For the assessment of drones losing GPS signal during a flight, students were split between "immediately land the drone" and "switch to manual flight mode," indicating confusion about the correct response when GPS is unavailable. For the drone's assessment distance from uninvolved people, most participants selected "50 meters," while some chose "100 meters" or "10 meters," suggesting uncertainty about regulatory distance requirements. As the RLO approach is not suitable for this kind of assessment, recommendations for additional instructional materials or interactive discussions should be introduced to reinforce the challenging concepts, and practical demonstrations or simulations should be incorporated to enhance understanding of GPS failure scenarios and regulatory distance requirements.

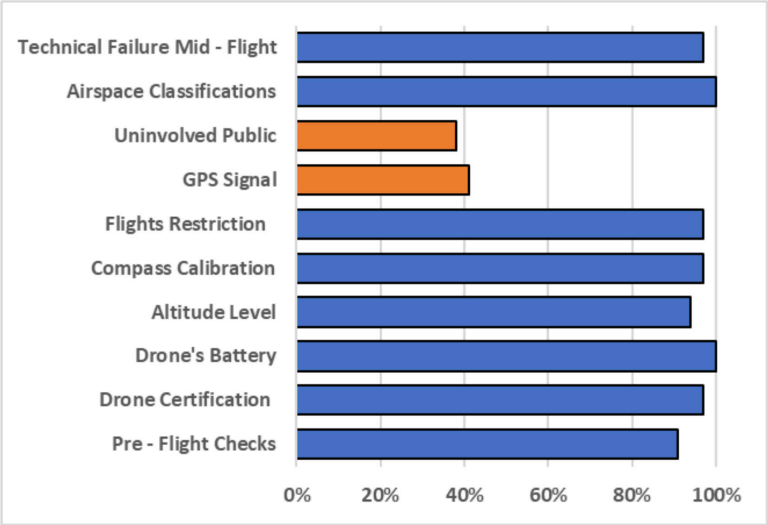

Figure 4. The RLO approach of the Safety and Regulations Module Assessment

4. CONCLUSION

The findings demonstrated significant improvements in knowledge across key areas, including drone components, applications, and safety regulations. The workshop effectively enhanced participants' comprehension, with notable increases in post-assessment scores, particularly in understanding flight controllers, GPS functionality, and video transmission components. However, some areas, such as airspace safety and regulatory compliance, showed slight declines, indicating the need for further reinforcement. The RLO approach has been implemented, and the results show significant improvement in participants' understanding. The results suggest that hands-on, competency-based training plays a crucial role in bridging the gap between theoretical knowledge and practical application. The insights gained from this workshop provide a foundation for refining drone education programs, integrating STEM and TVET principles, and enhancing industry collaboration. These findings support the need for a standardised curriculum, increased funding, and stronger partnerships between educational institutions and industry stakeholders.

Additionally, there exists a significant gap between commercial drone training and STEM and TVET-based drone education. While commercial drone training focuses on licensing and regulatory compliance, STEM and TVET training emphasise a broader educational framework that includes technical skills, innovation, and industry applications. The findings from the pre- and post-workshop assessments reveal that while participants demonstrated significant improvements in drone knowledge, certain areas, particularly airspace safety, regulatory compliance, and real-world industry applications, still require further reinforcement. The decline in post-assessment scores on airspace safety protocols and legal altitude limits suggests that students struggle to retain regulatory knowledge.

5. SUGGESTIONS

While this study provides a comprehensive analysis of STEM and TVET in drone education, further research is needed in several key areas, including longitudinal studies that assess the long-term impact of drone education on students' career prospects and industry development. Comparative Studies: Investigating how Malaysia's drone education framework compares with other leading countries. Technological Advancements: Exploring the role of emerging technologies such as artificial intelligence, machine learning, and 5G connectivity in drone education. Gender Inclusion: Examining strategies to encourage greater female participation in drone-related fields.

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8. AUTHOR'S CONTRIBUTION

Author1 conducted the fieldwork, compiled the literature review, and supervised the overall writing of the manuscript. Author2 was responsible for drafting the research methodology and performing data entry. Author3 conducted the statistical analysis and interpreted the results. Author4 managed the on-site activities during the drone workshop.

9. CONFLICT OF INTEREST DECLARATION

The authors have declared no conflict of interest in relation to this article.

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