

ENHANCING STUDENT ENGAGEMENT AND SKILLS IN TIMBER CONSTRUCTION THROUGH ARCHI-KIT: A 3D MODEL AND AUGMENTED REALITY (AR) APPROACH

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ABSTRACT

Objective: This study evaluates the usability and educational effectiveness of ARCHI-KIT, an innovative tool integrating 3D modelling and Augmented Reality (AR), to enhance timber construction education within Technical and Vocational Education and Training (TVET). It specifically aims to determine how these immersive technologies influence student understanding, engagement, and skills acquisition.

Research Method: A mixed-methods approach was utilized, involving 50 TVET students at Politeknik Port Dickson. Data collection combined quantitative measures via an adapted User Experience Questionnaire (UEQ) with qualitative insights from open-ended surveys and classroom observations. The study followed a convergent parallel design within a Design-Based Research (DBR) framework.

Findings: Results indicated high student approval across all dimensions: helpfulness ($M = 4.26$), learning engagement ($M = 4.18$), and learning effectiveness ($M = 4.20$). Qualitative feedback confirmed that ARCHI-KIT bridged the "visualization gap" for complex structural joints, increased learner motivation through interactivity, and promoted greater independence during practical sessions.

Originality: This research addresses a notable gap in literature by providing a learner-centered evaluation of domain-specific AR tools within the specific context of Malaysian TVET. It moves beyond technical specifications to offer empirical evidence on how immersive digital interventions can modernize traditionally hands-on, underexplored areas like timber construction.

Keywords: Timber Construction, TVET, 3D Modelling, Augmented Reality (AR), Digital Learning Tools.

1. INTRODUCTION

Technical and Vocational Education and Training (TVET) is essential for equipping learners with practical industry skills, particularly within Malaysia's construction sector. Timber construction demands high hands-on competence yet teaching it effectively in traditional settings remains challenging. Traditional education often fails to bridge the gap between theory and practical mastery due to abstract concepts, limited resources, and safety constraints. Relying on static 2D diagrams is often insufficient for learners who require visual and tactile experiences to understand complex spatial relationships in timber joints. Consequently, when students cannot visualize construction processes in real-time, their motivation and learning outcomes inevitably decline. In response, Education 4.0 has introduced immersive technologies like 3D modelling and augmented reality (AR) as promising tools for vocational learning. 3D modelling provides clear visualization of construction elements, while AR overlays virtual information onto real-world scenarios. These tools facilitate repeated practice in a risk-free environment, enhancing confidence and skill transfer without material waste or safety hazards. Despite these benefits, research often overlooks in-depth, learner-centered evaluations that assess usability and real-world impact on skill acquisition within a TVET framework.

There is currently a lack of studies exploring how these technologies align with the specific needs of Malaysian TVET students, who require practical and autonomous learning. This creates a notable gap in the literature regarding the effectiveness of domain-specific AR tools in vocational settings. Addressing these issues is crucial for maximizing the benefits of digital transformation and preparing graduates for the demands of modern engineering and architecture. Therefore, empirical evidence is needed to evaluate the integration of immersive tools in specific technical syllabi.

This study evaluates ARCHI-KIT, an innovative 3D and AR-based tool designed to bridge the gap between theory and practice in timber construction education. Through a user-centered approach, the research explores students' perceptions, usability, and the practical effectiveness of the tool within the DA30123 Working Drawing 2 syllabus at Politeknik Port Dickson. By prioritizing learner interaction, this study contributes to the evidence supporting immersive technologies in TVET. Ultimately, the findings aim to inform the development of learner-aligned digital tools that prepare students for the demands of Industry 4.0.

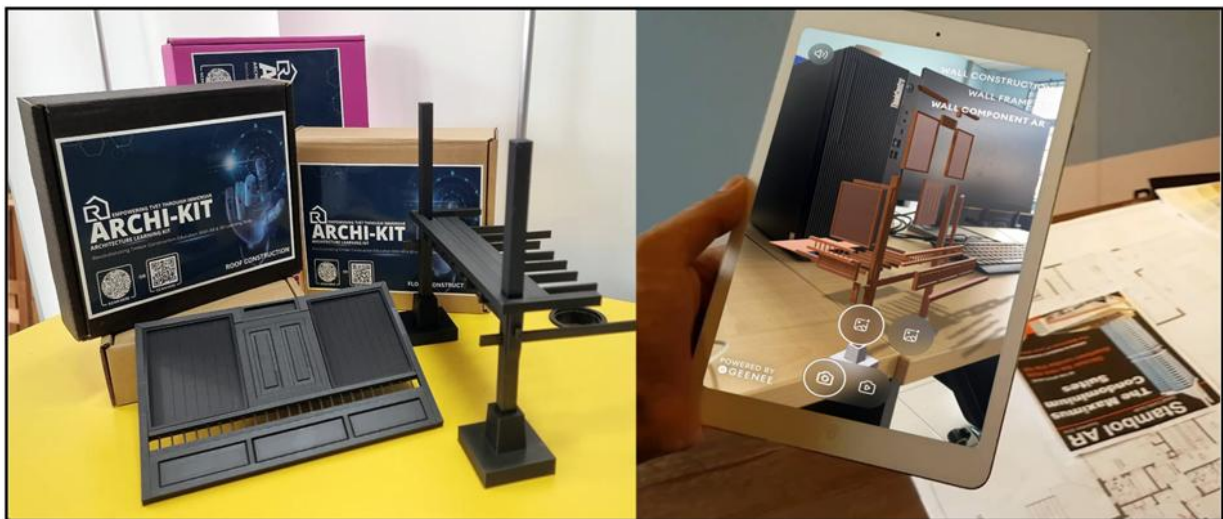


Figure 1: The ARCHI-KIT learning ecosystem featuring physical prototypes and Augmented Reality (AR) integration.

1.1. PROBLEM STATEMENT

Despite the importance of timber construction in the TVET curriculum, traditional pedagogical methods often fail to bridge the gap between theoretical knowledge and practical application. Students frequently struggle with abstract concepts and 2D diagrams that do not adequately represent complex 3D structural joints. Furthermore, physical constraints such as limited access to construction sites, high material costs for repeated practice, and significant safety risks restrict the opportunities for hands-on experiential learning. While immersive technologies like AR and 3D modelling offer a potential solution, most existing research focuses on technical specifications rather than learner-centered evaluations within the specific context of Malaysian TVET. There is a critical need to evaluate how these tools impact usability, student engagement, and actual skill acquisition in a real-world vocational setting.

1.2. RESEARCH OBJECTIVES

The primary objective of this study is to evaluate the usability and user experience of ARCHI-KIT, a digital learning tool that integrates 3D modelling and Augmented Reality (AR) in timber construction learning within Technical and Vocational Education and Training (TVET) settings. This research also aims to determine how immersive digital tools influence students' understanding, engagement, and skills development in practical learning environments.

The specific objectives are:

- To evaluate the usability and user experience of ARCHI-KIT in timber construction learning within TVET.
- To assess the impact of ARCHI-KIT on students' understanding, knowledge application, and skills acquisition in timber construction concepts.
- To examine how ARCHI-KIT influences students' engagement and motivation during practical timber construction learning.
- To explore the potential of ARCHI-KIT as a scalable digital learning innovation for vocational education.

2. LITERATURE REVIEW

2.1. TIMBER CONSTRUCTION EDUCATION IN TVET

Timber construction is a fundamental area within Technical and Vocational Education and Training (TVET), requiring learners to develop a combination of theoretical knowledge and practical skills. However, traditional pedagogical approaches in this field often face limitations that hinder effective skill acquisition. Typically, instruction in timber construction relies heavily on printed materials, 2D diagrams, and verbal explanations, which may be insufficient for learners who benefit more from visual and tactile experiences (Smith & Jones, 2021). Moreover, factors such as structural design limitations, restricted access to practical sessions or site visits, space constraints, and safety concerns further reduce opportunities for experiential learning. (Lee et al., 2022). These challenges are particularly significant in TVET contexts, where practical competency is essential. Research has shown that when students are unable to visualize construction processes or apply knowledge in real time, their motivation and learning outcomes may decline (Chen & Zhao, 2023). Consequently, there is a growing need to explore alternative instructional strategies and technologies that can bridge the gap between theory and practice in timber construction education.

2.2. MODELLING AND AUGMENTED REALITY IN VOCATIONAL EDUCATION

In response to traditional TVET limitations, immersive technologies like 3D modelling and Augmented Reality (AR) have emerged as promising innovations. These tools allow learners to interact with digital representations, enhancing comprehension and facilitating active learning environments. In vocational education, 3D modelling offers clear visualization of construction elements, while AR enables contextualized overlays of virtual information (Wang et al., 2021). Integrating these tools provides several benefits: increasing student engagement through interactive experiences (Yigitbas et al., 2023) and promoting better knowledge retention in spatially complex disciplines (Zhou et al., 2021). Furthermore, immersive tools enable repeated practice in risk-free environments, improving skill transfer and learner confidence (Radianti et al., 2020). This study examines ARCHI-KIT, a 3D and AR-based tool specifically for TVET timber construction, to inform effective technology integration in vocational education.

2.3. USER EXPERIENCE AND USABILITY IN EDUCATIONAL TECHNOLOGY

In recent years, user experience (UX) and usability have emerged as critical dimensions in evaluating educational technologies, particularly in vocational contexts where usability focuses on efficiency and UX encompasses emotional and cognitive responses. These factors significantly determine whether digital tools support or hinder educational outcomes, as poor usability can undermine advanced solutions by frustrating learners and reducing motivation. This is especially relevant for immersive tools like augmented reality (AR) and 3D modelling, where complex interfaces may impede the learning process. Recent studies emphasize that integrating user-centred

design (UCD) principles is essential to align technology with learners' expectations and skill levels. Prioritizing clear interface design and effective feedback enhances engagement and knowledge retention, which are crucial for technical training. For platforms like ARCHI-KIT, effectiveness depends on how intuitively students can control immersive content in real time. As noted by Yigitbas et al. (2023), learner satisfaction and task efficiency are vital for the long-term adoption and scalability of digital tools in TVET environments. Consequently, this study utilizes the User Experience Questionnaire (UEQ) and qualitative feedback to ensure ARCHI-KIT meets the practical needs of its users.

2.4. DIGITAL TRANSFORMATION IN TIMBER CONSTRUCTION EDUCATION

The rapid digital transformation within education has profoundly impacted technical and vocational fields, particularly through the introduction of Building Information Modeling (BIM), 3D modelling, and augmented reality (AR) to visualize complex structures. These technologies offer safe, cost-efficient environments for repeated practice and immediate feedback, supporting both cognitive understanding and motor skill acquisition without physical risks. Furthermore, the learner-centered nature of these tools promotes greater autonomy and aligns with competency-based vocational frameworks. Despite these advantages, successful integration requires addressing challenges such as educator upskilling, robust technical infrastructure, and equitable device access. Addressing these issues is essential to maximize the benefits of digital transformation in TVET contexts. ARCHI-KIT exemplifies this shift by combining 3D modelling and AR to bridge the gap between theoretical knowledge and practical skills. By facilitating immersive and interactive learning, it contributes to the modernization of vocational training and the development of job-ready graduates.

3. METHODOLOGY

This section outlines the research methodology used to evaluate ARCHI-KIT, a 3D and Augmented Reality (AR) tool for TVET timber construction education. It details the research design, participants, instruments, and analysis strategies, including the Design-Based Research (DBR) framework and parallel data collection illustrated in Figure 2.

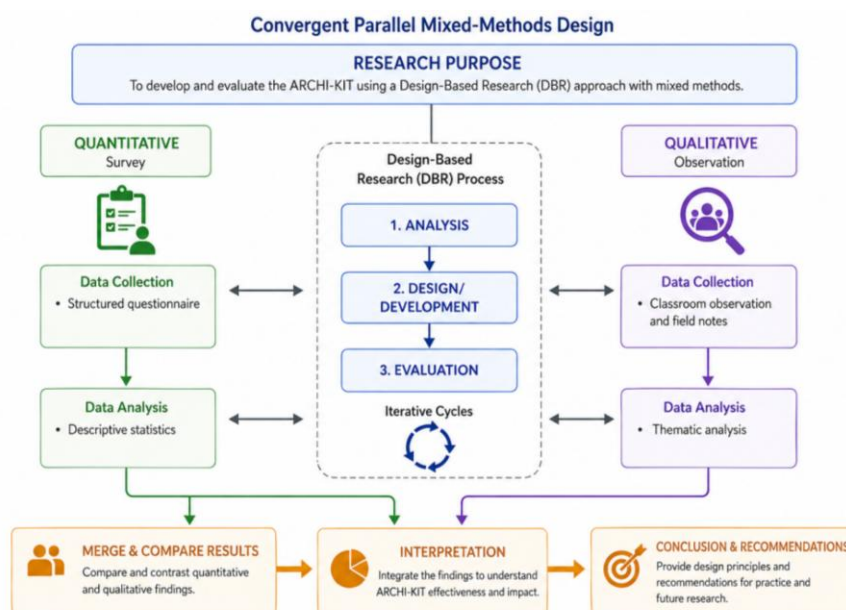


Figure 2: The ARCHI-KIT Research Framework using Convergent Parallel Mixed-Methods Design

3.1. RESEARCH DESIGN

This study employed a mixed-methods research design using a convergent parallel approach combined with a Design-Based Research (DBR) framework. The mixed-methods strategy allowed the integration of both quantitative and qualitative data collected concurrently to provide a comprehensive understanding of students' experiences with the ARCHI-KIT system. The convergent parallel design enabled simultaneous collection and separate analysis of both data types, followed by the merging of results during interpretation. The DBR framework guided the iterative development and refinement of ARCHI-KIT, allowing the tool to be tested and improved in authentic Technical and Vocational Education and Training (TVET) environments. This design ensured that both usability and pedagogical effectiveness were addressed through real-world classroom application and continuous feedback loops.

3.2. PARTICIPANTS

The participants in this study were TVET students enrolled in the timber construction topic under the DA30123 Working Drawing 2 syllabus at Politeknik Port Dickson. A total of 50 students were invited to participate, and all provided valid responses. This sample size corresponds with the Krejcie and Morgan table's recommendation for a population of this size, ensuring statistical adequacy. A purposive sampling method was employed, selecting only students who had completed hands-on sessions using the ARCHI-KIT system, thereby ensuring that all participants had relevant and practical experience with the tool.

3.3. INSTRUMENTS AND TOOLS

Data were collected using a structured questionnaire developed through Google Forms, comprising both closed-ended Likert-scale items and open-ended questions. The instrument was organized into three sections: (A) background information, (B) experience with ARCHI-KIT, and (C) learning impact. The questionnaire was designed to assess user perceptions, system usability, and the educational value of ARCHI-KIT in the context of timber construction training. Quantitative items measured dimensions such as familiarity, helpfulness, engagement, confidence, and perceived learning effectiveness. Open-ended questions captured students' suggestions, reflections, and qualitative insights regarding their experiences with the tool. The User Experience Questionnaire (UEQ) framework was adapted to suit the learning objectives and context of TVET education.

3.4. DATA COLLECTION PROCEDURES

Participants engaged with ARCHI-KIT during comprehension and practical training sessions in class, where they used the system to learn about the construction of timber joints through physical 3D models and Augmented Reality (AR) components. The AR content was accessed by scanning specific markers and spatial elements, allowing students to interact with digital overlays in real time. Immediately following the session, an online questionnaire was distributed to the students. They completed the survey voluntarily, providing feedback based on their direct experience with ARCHI-KIT in learning timber construction. The data collection period lasted one week, allowing sufficient time for student reflection and thoughtful responses, while ensuring an adequate number of responses. Additionally, observation notes were recorded during training sessions using video recordings and structured observation forms to help contextualize both quantitative and qualitative findings.

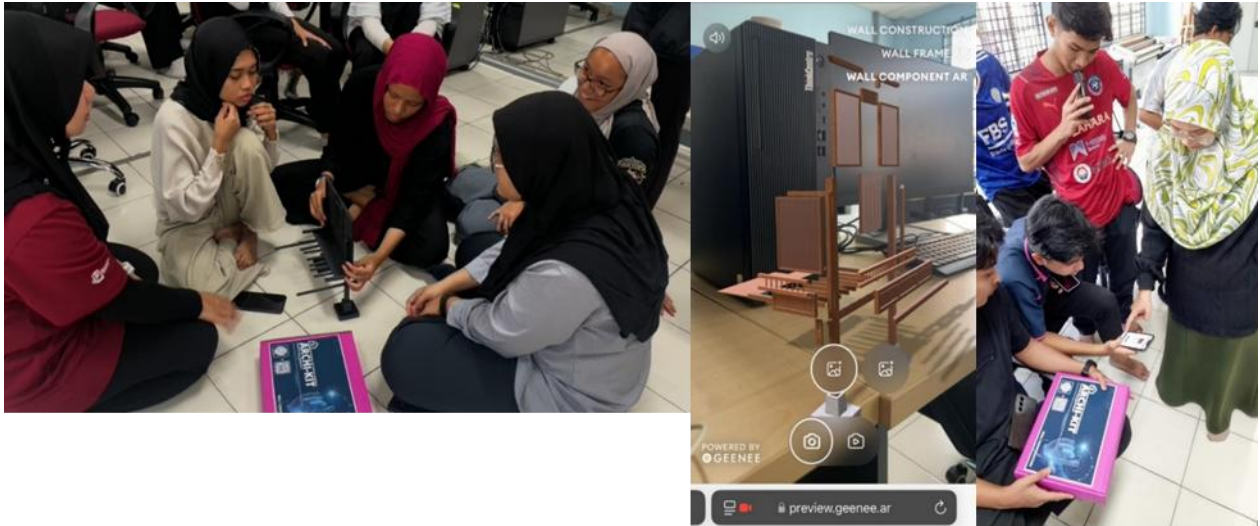


Figure 3: Students engaging in collaborative learning sessions using ARCHI-KIT physical models and AR components.

3.5. DATA ANALYSIS

Data analysis followed a convergent parallel mixed-methods approach, in which quantitative and qualitative data were analyzed separately but concurrently, and later integrated during interpretation. The quantitative data, obtained from closed-ended Likert-scale questionnaire items, were analyzed using descriptive statistics, including frequencies, means, and standard deviations, to evaluate participants' perceptions of ARCHI-KIT in terms of usability, helpfulness, engagement, and learning effectiveness. The results were processed using Microsoft Excel, based on response data generated from Google Forms, to identify central tendencies and patterns across key user experience dimensions.

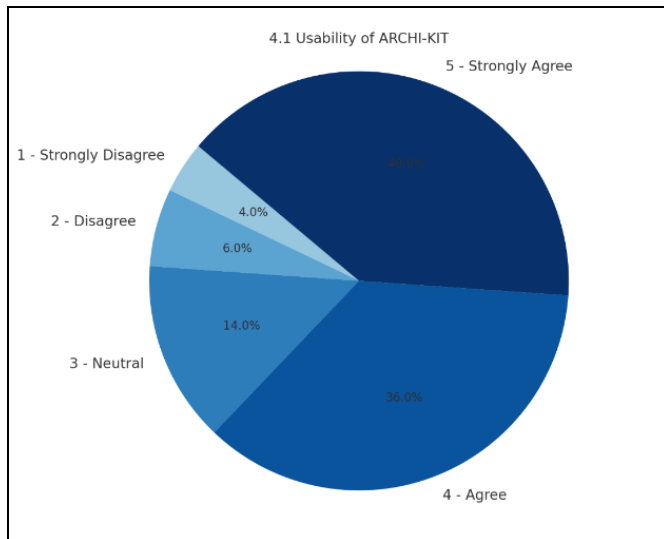
Meanwhile, the qualitative data, derived from open-ended responses, were analyzed using thematic analysis. A manual coding process was employed to identify recurring themes, user suggestions, and feedback related to system design, usability challenges, and learning value. The findings from both data sets were then merged and interpreted collectively to provide a comprehensive understanding of the impact and effectiveness of ARCHI-KIT. This integrated analysis also guided the iterative improvement of the tool, in line with the principles of the Design-Based Research (DBR) framework.

4. RESULTS AND FINDINGS

The results of this study are derived from a convergent parallel mixed-methods analysis of 50 TVET students, integrating quantitative data on usability and effectiveness with qualitative insights from observations and feedback. The findings demonstrate a high level of acceptance, with students consistently rating ARCHI-KIT as a superior alternative to traditional 2D pedagogical methods for bridging the gap between theory and practical mastery.

4.1. QUANTITATIVE RESULTS

4.1.1. USABILITY OF ARCHI-KIT (NAVIGATION, EASE OF USE)



Scale	Frequency
1 (Strongly Disagree)	2
2 (Disagree)	3
3 (Neutral)	7
4 (Agree)	18
5 (Strongly Agree)	20

Figure 4: Frequency distribution and descriptive statistics for responses on ARCHI-KIT's usability in teaching and learning within TVET.

Quantitative analysis of student feedback revealed a high level of usability for ARCHI-KIT ($M = 3.98$, $SD = 1.03$), demonstrating strong student acceptance of the system's navigation, ease of use, and overall user experience within the TVET learning environment. These findings directly address the first research objective, which aimed to evaluate the usability and user experience of ARCHI-KIT in timber construction learning. The majority of respondents agreed that the tool was accessible, intuitive, and effective in supporting teaching and learning activities. This suggests that the integration of 3D modelling and Augmented Reality (AR) within ARCHI-KIT successfully enhanced students' interaction with learning materials while minimizing usability challenges during practical timber construction sessions.

4.1.2. HELPFULNESS OF 3D MODELS

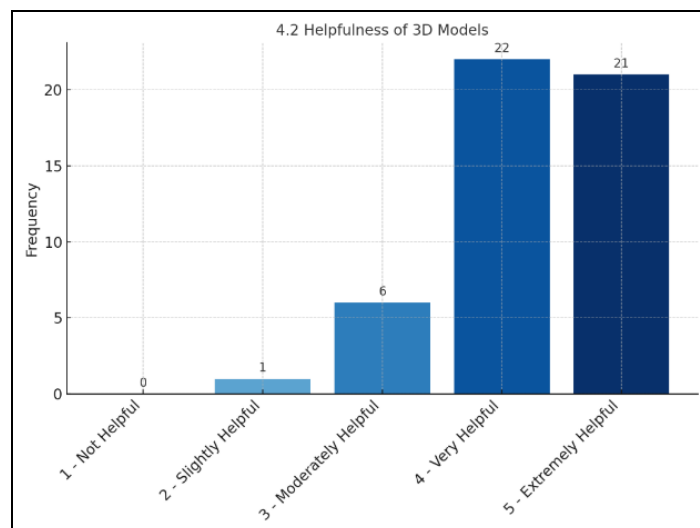


Figure 5: Result of the student feedback on how helpful ARCHI-KIT's 3D models were in enhancing understanding of timber construction.

The 3D models were rated as highly helpful in enhancing students' understanding of timber construction concepts ($M = 4.26$, $SD = 0.73$), with over 85% of respondents selecting the highest levels of helpfulness. These findings directly support the second research objective, which aimed to assess the impact of ARCHI-KIT on students' understanding, knowledge application, and skills acquisition in timber construction learning. The high mean score indicates that the integration of 3D modelling significantly improved students' ability to visualize and comprehend complex structural components and construction processes. This suggests that ARCHI-KIT effectively bridged the gap between theoretical instruction and practical understanding by enabling students to interact with realistic digital representations of timber joints and assemblies.

4.1.3. LEARNING ENGAGEMENT

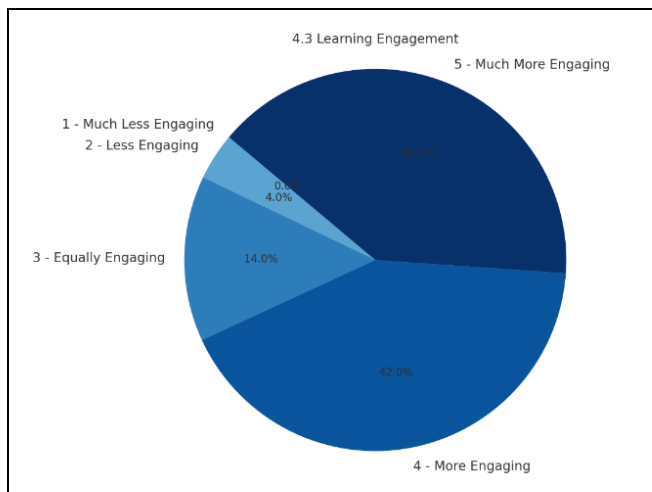


Figure 6: Frequency comparative results showing students' reported engagement with ARCHI-KIT compared to conventional classroom methods.

Most participants perceived ARCHI-KIT as more engaging than conventional learning methods ($M = 4.18$, $SD = 0.84$), indicating a positive impact on students' motivation and participation during timber construction learning activities. These findings directly address the third research objective, which aimed to examine how ARCHI-KIT influences students' engagement and motivation in practical learning environments. The high engagement ratings suggest that the interactive integration of 3D modelling and Augmented Reality (AR) created a more immersive and stimulating learning experience compared to traditional classroom approaches. This demonstrates that ARCHI-KIT successfully promoted active participation, learner interest, and greater enthusiasm toward understanding timber construction concepts.

4.1.4. LEARNING EFFECTIVENESS

The results regarding learning effectiveness are presented in figure 7. The results indicate that most students perceived ARCHI-KIT to be more effective than conventional learning tools in helping them understand and apply timber construction concepts ($M = 4.20$, $SD = 0.75$). These findings support the fourth research objective, which sought to explore the potential of ARCHI-KIT as a scalable digital learning innovation for vocational education. The high effectiveness ratings indicate that ARCHI-KIT not only enhanced conceptual understanding and practical application but also demonstrated strong potential as an innovative instructional tool that can support

modern TVET pedagogical practices. The integration of immersive technologies within ARCHI-KIT highlights its capability to contribute toward digital transformation and the broader adoption of interactive learning solutions aligned with Industry 4.0 educational demands.

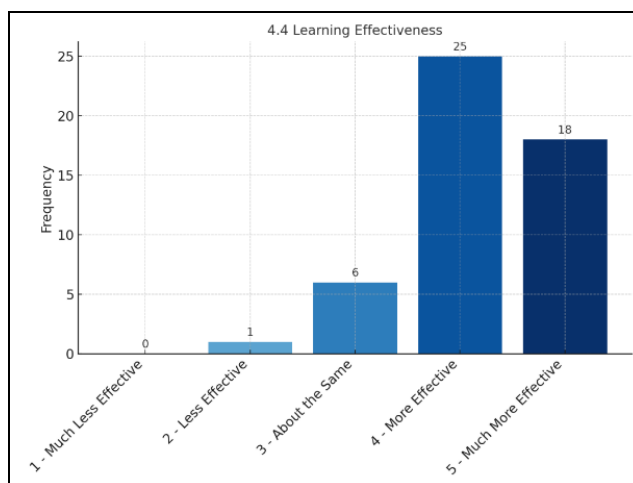


Figure 7: Frequency effectiveness ratings of ARCHI-KIT as a learning tool relative to traditional approaches in the timber construction curriculum.

4.1.5. QUANTITATIVE DATA SUMMARY TABLE

Table 1: Summary of Quantitative Findings: Consolidated table of means, standard deviations, and key observations from all quantitative survey items (Sections 4.1.1 to 4.1.4).

Section	Question	Scale (1–5)	Frequency per Scale Point	Mean	Standard Deviation
4.1.1 Usability of ARCHI-KIT	“I am familiar with Augmented Reality (AR) and believe that ARCHI-KIT has potential to support teaching and learning in TVET.”	1 – Strongly Disagree: 2 2 – Disagree: 3 3 – Neutral: 7 4 – Agree: 18 5 – Strongly Agree: 20	3.98	±1.03	Most respondents agreed on the potential usability of ARCHI-KIT, with minimal disagreement.
4.1.2 Helpfulness of 3D Models	“How helpful were the 3D models in improving your understanding of timber construction?”	1 – Not Helpful: 0 2 – Slightly Helpful: 1 3 – Moderately Helpful: 6 4 – Very Helpful: 22 5 – Extremely Helpful: 21	4.26	±0.73	The majority found 3D models helpful, with over 85% choosing 4 or 5.

4.1.3 Learning Engagem ent	“How engaging did you find the ARCHI-KIT experience compared to traditional classroom methods?”	1 – Much Less Engaging: 0 2 – Less Engaging: 2 3 – Equally Engaging: 7 4 – More Engaging: 21 5 – Much More Engaging: 20	4.18	±0.84	The AR experience was generally rated more engaging than traditional methods.
4.1.4 Learning Effective ness	“Compared to traditional learning methods, how effective was ARCHI-KIT in helping you learn?”	1 – Much Less Effective: 0 2 – Less Effective: 1 3 – About the Same: 6 4 – More Effective: 25 5 – Much More Effective: 18	4.20	±0.75	Most students found ARCHI-KIT more effective than conventional learning tools.

4.2. QUALITATIVE FINDINGS: THEMATIC ANALYSIS OF OPEN-ENDED RESPONSES

Thematic analysis of the open-ended responses revealed six dominant themes regarding students' experiences with ARCHI-KIT. These themes provide deeper insight into how the tool influenced their learning process and motivation.

4.2.1. IMPROVED CONCEPTUAL UNDERSTANDING AND VISUALIZATION

Students consistently reported that ARCHI-KIT bridged the gap between theoretical drawings and practical understanding. The use of Augmented Reality (AR) was cited as a critical factor in helping students visualize complex timber joints that were previously difficult to grasp via textbooks. One student noted, “I finally understand how timber joints actually work! The AR animation makes it so much clearer than just looking at drawings”. This sentiment was echoed by others who found it easier to retain technical information after interacting with the digital models.

4.2.2. INTERACTIVITY, ENGAGEMENT, AND MOTIVATION

The tool's interactive nature transformed the learning environment into a more immersive experience. Participants frequently described the process as "fun" and "enjoyable," which directly boosted their motivation to participate in class. A participant highlighted the effectiveness of this approach, stating, “I love how I can hold the 3D model... feels like learning through play but very effective”.

4.2.3. PEDAGOGICAL VALUE AND FUTURE RECOMMENDATIONS

Beyond immediate learning, students recognized the alignment of ARCHI-KIT with Industrial Revolution 4.0 (IR 4.0) standards in the Malaysian education system. Many suggested that the tool should become a compulsory component of the timber construction syllabus. For future iterations, students recommended technical enhancements such as mobile application development, the inclusion of gamification elements like leaderboards, and broader content covering sustainable "green" architecture.

4.2.4. SUMMARY OF QUALITATIVE FEEDBACK

To provide a clear overview of the qualitative data, the identified themes and representative evidence are consolidated in Table 2.

Table 2: Thematic Summary of Student Feedback on ARCHI-KIT

Theme	Key Evidence (Student Quotes)
Understanding	"When I use AR, I immediately understand how this connection works."
Engagement	"Learning is more fun... feels like learning through play but very effective."
Interactivity	"Include more interactive elements such as quizzes or real-time feedback."
Pedagogy	"This kit really aligns with IR 4.0 in the education system."
Expansion	"Add more detailed 3D models of various timber joints and structures."

The thematic analysis confirms that ARCHI-KIT is well-received among students in timber construction education, effectively enhancing their conceptual understanding, engagement, and overall learning experience. The qualitative data suggests that future iterations of the tool could benefit from more interactive and collaborative features, gamification, expanded content, and closer alignment with emerging educational technologies. These insights provide a valuable roadmap for refining ARCHI-KIT and successfully integrating it further into the TVET curriculum to meet the evolving needs of vocational learners.

5. DISCUSSION

This chapter synthesizes the quantitative and qualitative findings to evaluate the educational value of ARCHI-KIT in timber construction education. The discussion aligns the results with research objectives and existing literature to provide a holistic view of immersive technologies in Technical and Vocational Education and Training (TVET).

5.1. EVALUATION OF LEARNING EFFECTIVENESS AND SPATIAL VISUALIZATION

The quantitative results demonstrated a strong consensus on learning effectiveness ($M=4.20$) and the helpfulness of 3D models ($M=4.26$). These high scores suggest that ARCHI-KIT effectively bridges the "visualization gap" inherent in traditional timber construction education, where 2D drawings often fail to convey complex 3D joints. This finding aligns with Zhou et al. (2021), who noted that immersive tools enhance spatial understanding in technically complex subjects. Qualitative feedback further validated this, as students reported that AR animations provided conceptual clarity that textbooks could not offer. This triangulation confirms that digital interactivity is a critical requirement for modernizing TVET pedagogical frameworks.

5.2. IMPACT ON STUDENT ENGAGEMENT AND MOTIVATION

The engagement mean of 4.18 indicates that ARCHI-KIT successfully sustained learner interest compared to conventional methods. The qualitative "learning through play" theme suggests that the tool effectively leverages experiential learning. These results resonate with Yigitbas et al. (2023), who argued that the novelty and interactivity of AR environments foster higher intrinsic motivation. In a TVET setting, where learner autonomy is essential, the high engagement levels recorded here suggest that ARCHI-KIT can serve as a catalyst for more independent and student-centered learning.

5.3. PRACTICAL IMPLICATIONS FOR TVET AND INDUSTRY 4.0

The integration of 3D and AR technologies via ARCHI-KIT represents a significant step toward aligning vocational training with Industrial Revolution 4.0 (IR 4.0)

standards. By providing a low-risk, cost-effective digital environment for repeated practice, ARCHI-KIT addresses the safety and material waste concerns prevalent in traditional workshops. The study's findings suggest that such tools are not merely instructional aids but are essential components for developing job-ready graduates who are proficient with digital construction workflows.

5.4. SYNTHESIS OF USABILITY AND USER EXPERIENCE

With a usability mean of 3.98, the study reinforces the importance of User-Centered Design (UCD) in educational technology. Students' ability to navigate the system effectively was a prerequisite for the learning gains recorded. Consistent with Radianti et al. (2020), these findings emphasize that for an AR tool to be educationally impactful, the technology must be accessible and intuitive to prevent cognitive overload among learners.

6. CONCLUSION AND RECOMMENDATIONS

This chapter summarizes the study's findings, contributions, and practical recommendations for future research and implementation of ARCHI-KIT in TVET timber construction education.

6.1. SUMMARY OF FINDINGS

This mixed-methods study evaluated ARCHI-KIT's effectiveness in timber construction education. Quantitative results showed strong support for helpfulness (M=4.26), engagement (M=4.18), and learning effectiveness (M=4.20), indicating a user-friendly and impactful experience. Qualitative analysis confirmed that ARCHI-KIT improved conceptual clarity and student motivation, with students highlighting its value in visualizing complex structures.

6.2. CONTRIBUTIONS TO KNOWLEDGE

This research contributes to the literature on immersive technologies by providing a learner-centered evaluation of domain-specific AR and 3D tools within a TVET context. It offers empirical evidence that these immersive tools effectively enhance both conceptual understanding and student engagement in skill-based disciplines. By focusing on timber construction, a traditionally underexplored area in digital learning, this study successfully addresses a notable research gap and provides a replicable digital intervention model for other vocational learning contexts.

6.3. RECOMMENDATIONS

- 1) Curriculum Integration: Integrate ARCHI-KIT into existing syllabi to supplement learning where physical resources are limited.
- 2) Professional Development: Provide specialized AR/3D technology training for instructors to ensure effective implementation.
- 3) Technical Enhancement: Update tools with interactive quizzes, real-time feedback, and multilingual support for better personalization.
- 4) Future Research: Conduct experimental studies comparing ARCHI-KIT with traditional methods and explore integration with Building Information Modeling (BIM) or Virtual Reality (VR).

6.4. CONCLUSION

ARCHI-KIT has proven to be a valuable, learner-friendly immersive tool that bridges the gap between theory and practice in timber construction. By aligning vocational education with Industry 4.0 demands, this study demonstrates that well-designed digital tools can significantly enhance practical learning outcomes and prepare students for real-world environments.

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