International Journal of Modern Education
EISSN: 2637-0905
Volume 7 Issue 28 (December 2025) PP. 1097-1118
DOI: 10.35631/IJMOE.728076

INTERNATIONAL JOURNAL OF MODERN EDUCATION (IJMOE)
www.ijmoe.com

METAKELAS AND STUDENT TECHNOLOGY ACCEPTANCE: TRANSFORMING ONLINE CLASS USING METAVERSE LEARNING ADOPTION BASED ON PERCEIVED USEFULNESS, PERCEIVED EASE OF USE, AND BEHAVIORAL INTENTION

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Article Info:

Article history:
Received date: 30.10.2025
Revised date: 20.11.2025
Accepted date: 18.12.2025
Published date: 28.12.2025

To cite this document:

Abd Razak, A. H., Ismail, S. A., Mohamed, N. F. F., Ibrahim, M., & Mohmad Yazam, S. S. N. (2025). Metakelas And Student Technology Acceptance: Transforming Online Class Using Metaverse Learning Adoption Based on Perceived Usefulness, Perceived Ease of Use, And

Abstract:

The COVID-19 pandemic accelerated the adoption of online learning platforms, yet traditional video conferencing tools have proven inadequate in sustaining student engagement, presence, and cognitive focus. This study examines student acceptance of MetaKelas, a browser-based metaverse learning platform, through the lens of the Technology Acceptance Model (TAM). The primary objective was to investigate how perceived usefulness, perceived ease of use, and attitude toward use influence behavioural intention to adopt metaverse platforms in higher education. A quantitative quasi-experimental post-test only design was employed, involving foundation and undergraduate students at Universiti Utara Malaysia who used MetaKelas across two consecutive academic semesters (A241 and A242). Data were collected through structured online questionnaires measuring TAM constructs using seven-point Likert scales and analysed using partial least squares structural equation modelling (PLS-SEM). The measurement model demonstrated excellent reliability and validity, with all constructs exceeding recommended thresholds for internal consistency (CR > 0.95) and convergent

International Journal of Modern Education
IJMOE
EISSN: 2637-0905
Volume 7 Issue 28 (December 2025) PP. 1097-1118
DOI: 10.35631/IJMOE.728076

Behavioral Intention. *International Journal of Modern Education, 7* (28), 1097-1118.

DOI: 10.35631/IJMOE.728076

validity (AVE > 0.81). The structural model exhibited substantial explanatory power, with R^2 values of 0.733 for attitude and 0.769 for behavioural intention. Results revealed that perceived usefulness significantly predicted attitude toward use ($\beta = 0.650$, $p = .005$), while perceived ease of use showed no significant effect ($\beta = 0.230$, $p = .298$). Attitude strongly predicted behavioural intention ($\beta = 0.877$, $p < .001$) and significantly mediated the relationship between perceived usefulness and behavioural intention ($\beta = 0.570$, $p = .005$), but not between perceived ease of use and behavioural intention ($\beta = 0.202$, $p = .303$). These findings suggest that among digitally fluent students, demonstrating educational value matters more than interface simplicity in driving metaverse adoption. The study contributes empirical evidence supporting TAM's applicability to immersive learning environments and offers practical implications for educators and instructional designers seeking to implement accessible, avatar-based platforms as scalable alternatives to traditional video conferencing in online education.

Keywords:

Metaverse Learning, Technology Acceptance Model, Perceived Usefulness, Attitude Mediation, Online Education, Immersive Learning Environments

Introduction

The COVID-19 pandemic accelerated the large-scale adoption of online learning in higher education. Universities worldwide rapidly shifted to digital platforms such as Zoom, Microsoft Teams, Google Meet, and Webex to replace face-to-face class. Although this transition ensured continuity of teaching and learning, it also exposed fundamental limitations of conventional video conferencing tools. Prolonged screen-based interaction reduced social presence, and limited opportunities for meaningful peer engagement have contributed to cognitive fatigue and declining student motivation, a phenomenon widely described as "Zoom fatigue" (Bailenson, 2021; Castelli & Sarvary, 2021). As online learning becomes a permanent feature of higher education rather than an emergency response, questions regarding the adequacy of existing platforms have become increasingly pressing.

Most video conferencing platforms are designed primarily for corporate communication rather than pedagogical interaction. Their interface structures privilege one-way content delivery and fragmented visual attention, often reducing students to passive participants. The absence of spatial cues, embodied interaction, and informal peer engagement limits students' sense of co-presence, which is central to effective learning communities. Empirical studies conducted during and after the pandemic consistently report feelings of isolation, reduced interaction quality, and diminished engagement among students enrolled in fully online courses (Dhawan, 2020; Hodges et al., 2020; Means et al., 2013). These challenges suggest that simply replicating face-to-face instruction through video conferencing does not adequately address the social and cognitive dimensions of learning.

In response to these limitations, immersive learning technologies have gained increasing scholarly and institutional attention. Virtual reality and metaverse-based environments offer interactive, spatially organised, and avatar-mediated experiences that differ fundamentally from flat, screen-based platforms. Prior research indicates that immersive environments can

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enhance engagement, motivation, and learning retention by fostering experiential and collaborative learning (Radianti et al., 2020; Wu et al., 2024). However, most empirical studies in this area focus on head-mounted virtual reality systems that require specialised hardware, substantial financial investment, and high technical readiness. These requirements limit their scalability and raise concerns about accessibility and educational equity.

Browser-based metaverse platforms represent a potentially viable alternative. By operating on standard devices and using third-person avatars to simulate spatial and social interaction, such platforms aim to preserve key affordances of immersive learning while avoiding the infrastructural barriers associated with full virtual reality systems. Despite growing interest in the educational metaverse, empirical evidence regarding students' acceptance of browser-based metaverse learning remains limited. Existing studies often treat metaverse tools as experimental novelties or short-term interventions, rather than embedding them into sustained curricular practice. Moreover, there is a lack of theory-driven research examining the psychological mechanisms that shape students' willingness to adopt metaverse platforms for formal learning.

The Technology Acceptance Model (TAM) provides a well-established framework for understanding users' adoption of new technologies. Originally developed by Davis (1989), TAM posits that perceived usefulness and perceived ease of use influence users' attitudes toward a technology, which in turn shape behavioural intention to use it. While TAM has been widely applied in educational technology research, most studies focus on conventional learning management systems or mobile learning applications. Its application to immersive, avatar-based metaverse learning environments remains underexplored. It is unclear whether perceived usefulness and perceived ease of use play similar roles in shaping students' attitudes and intentions in immersive contexts, especially among digitally fluent learners.

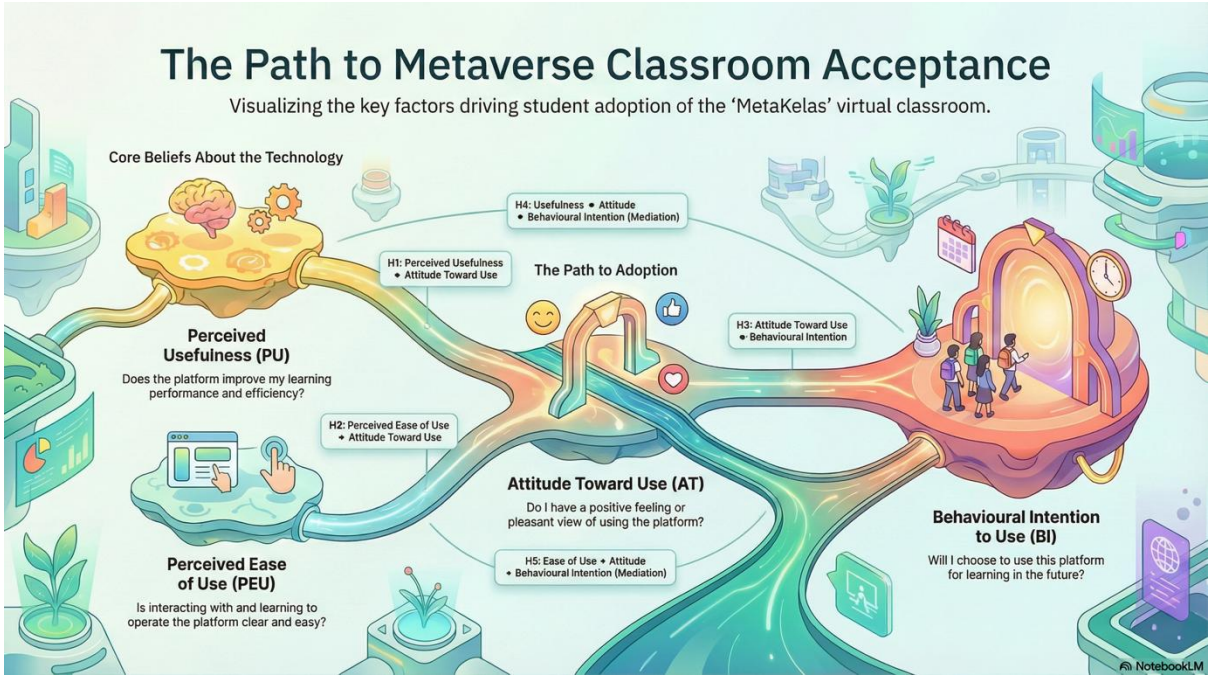

Figure 1: MetaKelas as Metaverse Adaption in Online Class

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This study (Figure 1) addresses these gaps by examining students' acceptance of MetaKelas, a browser-based metaverse learning platform implemented across two consecutive academic semesters at Universiti Utara Malaysia (UUM). Drawing on the TAM, the study investigates the relationships between perceived usefulness, perceived ease of use, attitude toward use, and behavioural intention to adopt metaverse learning. Unlike prior research that relies on brief exposure or hypothetical scenarios, this study examines sustained use of the platform within authentic teaching and learning contexts.

By doing so, the study makes three important contributions. First, it extends the application of TAM to browser-based metaverse learning environments, a context that remains empirically underrepresented in existing literature. Second, it provides evidence on the relative importance of perceived usefulness and perceived ease of use in shaping students' attitudes and intentions toward immersive learning platforms. Third, it demonstrates that metaverse-based learning has relevance beyond emergency remote teaching, offering a scalable and accessible alternative for post-pandemic online education. These contributions provide both theoretical insight into technology acceptance in immersive environments and practical guidance for educators and institutions seeking to enhance the quality of online learning as in Figure 2.

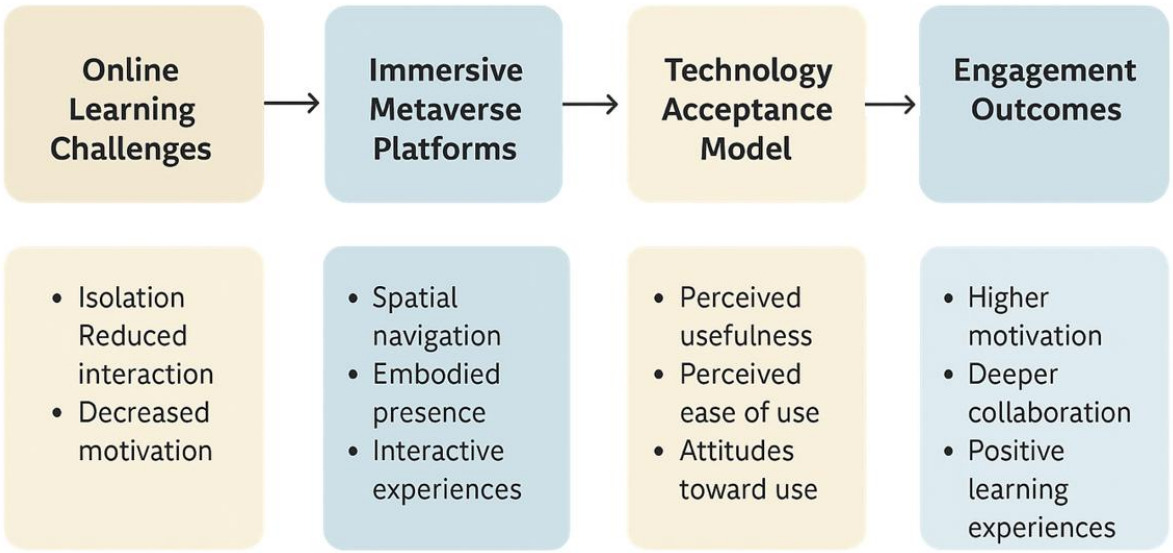

Figure 2: Flow of the MetaKelas Initiative

Literature Review

The Metaverse as an Educational Platform

The integration of metaverse technologies into formal education represents a significant departure from conventional online learning paradigms. While video conferencing platforms have dominated distance education for over a decade, their limitations in fostering meaningful engagement and presence have become increasingly apparent. The metaverse, broadly defined as persistent, synchronous, three-dimensional virtual environments where users interact through digital avatars, offers an alternative model that emphasises spatial navigation, embodied presence, and social immersion (Boztas et al., 2025).

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Unlike virtual reality systems that require specialised hardware, browser-based metaverse platforms operate on standard computing devices, making them potentially more accessible for large-scale educational deployment. This accessibility, combined with the promise of enhanced engagement, positions the metaverse as a viable solution to ongoing challenges in online education. However, despite growing institutional interest, empirical evidence on student acceptance and learning outcomes in metaverse environments remains underdeveloped, particularly in contexts where such platforms are embedded within structured curricula rather than treated as experimental novelties.

Theoretical Foundation: The Technology Acceptance Model

Understanding how students perceive and adopt new educational technologies requires theoretical grounding. The Technology Acceptance Model, first articulated by Davis (1989), provides a robust framework for examining user adoption by positing that two primary beliefs, perceived usefulness and perceived ease of use, shape attitudes toward technology, which in turn influence behavioural intention to use. Davis's original formulation emerged from organisational contexts in which information systems were being introduced to employees with varying degrees of technological experience.

Central to TAM is the proposition that users will adopt a technology if they believe it will improve their performance (usefulness) and if they perceive it as requiring minimal effort (ease of use). The model's elegance lies in its parsimony; by focusing on these two belief constructs and their attitudinal and behavioural consequences, TAM offers predictive power without the complexity of models that incorporate dozens of variables. Davis operationalised perceived usefulness as the degree to which a person believes that using a particular system would enhance their job performance, while perceived ease of use refers to the degree to which a person believes that using the system would be free of effort. Both constructs were shown to significantly influence user attitudes, which in turn predicted actual system use.

Extensions and Meta-Analytic Evidence of TAM

Venkatesh and Davis (2000) extended the original TAM through a series of longitudinal field studies conducted across four different organisational settings. Their theoretical extension, known as TAM2, incorporated social influence processes and cognitive instrumental processes to better explain perceived usefulness. Across their studies involving 156 workers, they found that subjective norm, image, job relevance, output quality, and result demonstrability all contributed to shaping perceptions of usefulness. Critically, Venkatesh and Davis confirmed that attitude toward using technology mediates the relationship between belief constructs and behavioural intention.

Their longitudinal design allowed them to track how perceptions changed over time, revealing that initial scepticism often gave way to acceptance once users experienced tangible benefits. However, their work focused exclusively on workplace settings where technology adoption was often mandatory or strongly encouraged by management. Whether these patterns hold in educational contexts, where students have more autonomy and where the stakes of non-adoption differ considerably, remains an open question.

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A critical meta-analysis by King and He (2006) synthesised findings from 88 published studies that employed TAM, examining the model's validity across diverse contexts and populations. Their analysis confirmed that perceived usefulness consistently exerts a more substantial influence on behavioural intention than perceived ease of use, with average correlations of 0.51 and 0.40, respectively. This finding has important implications for educational technology adoption, suggesting that demonstrating functional value may matter more than simplifying interfaces, especially among digitally proficient student populations.

The strength of these relationships varies with several moderating factors, including whether technology use is mandatory or voluntary, the type of technology under study, and the cultural context in which adoption occurs King and He (2006). Interestingly, their meta-analysis revealed that the role of attitude as a mediator was less consistent than originally theorised by Davis. In some contexts, perceived usefulness directly predicted behavioural intention without meaningful attitudinal mediation, while in others, attitude played a central mediating role. These contradictory patterns suggest that the psychological processes underlying technology acceptance may be more context-dependent than the original TAM framework acknowledged.

Immersive Learning Environments: Benefits and Barriers

Immersive learning environments, particularly virtual reality (VR) platforms, have demonstrated substantial benefits in higher education, including increased student engagement, motivation, and deeper learning experiences (Hussain, 2023; Hwang et al., 2023). Systematic reviews indicate that VR facilitates experiential and interactive learning, allowing students to explore simulated environments that foster cognitive and affective engagement beyond what conventional online platforms can provide (Hu, Ito, & Igarashi, 2023; Frontiers in Virtual Reality, 2025).

Despite these advantages, implementing immersive VR in educational contexts presents significant challenges, including high hardware costs, technical difficulties, accessibility barriers for students with disabilities, and the need for sufficient digital literacy (Creed et al., 2024) These limitations highlight a critical tension: while immersive environments can enhance learning outcomes, practical adoption is constrained by infrastructural, financial, and pedagogical barriers. Consequently, there is growing interest in browser-based, avatar-mediated metaverse platforms, which aim to preserve the engagement benefits of immersive VR while reducing hardware and accessibility constraints (Hussain et al., 2024).

The Mediating Role of Attitude in Technology Acceptance

The mediating role of attitude in technology acceptance has received substantial theoretical attention but inconsistent empirical treatment. Davis (1989) originally proposed that attitude fully mediates the relationship between belief constructs and behavioural intention, meaning that perceived usefulness and ease of use influence behaviour only through their effect on attitudes. However, subsequent research has challenged this proposition. Venkatesh and Davis (2000) found that in some contexts, perceived usefulness had both direct effects on behavioural intention and indirect effects mediated through attitude.

This dual pathway suggests that users may intend to adopt a technology both because they hold positive attitudes toward it (affective route) and because they rationally assess its instrumental value (cognitive route). The existence of these parallel pathways has important implications

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for educational interventions aimed at promoting technology adoption. If attitude mediates the relationship, then strategies that foster positive emotional responses to the technology become crucial. If direct pathways dominate, then clearly demonstrating functional benefits may suffice regardless of users' affective states.

TAM in Educational Contexts: Individual Differences and Moderation

Tarhini et al. (2017) examined e-learning adoption in developing countries, applying TAM within a structural equation modelling framework to understand how individual differences moderate technology acceptance. Their study involved 569 students across multiple institutions and found that while perceived usefulness remained a stable predictor of behavioural intention across demographic groups, the role of perceived ease of use varied considerably. Specifically, they found that among users with higher levels of prior computer experience and technological self-efficacy, ease of use became a less significant predictor of attitude and intention.

This suggests that as students become more comfortable with digital interfaces generally, the specific usability of any given platform becomes less decisive in adoption decisions. Their findings also revealed gender differences, with female students placing greater emphasis on ease of use than male students, although both groups valued perceived usefulness equally. However, their research just focusing on traditional learning management systems, primarily Moodle and Blackboard, leaves unresolved the question of whether these patterns hold in more immersive, spatially oriented environments like the metaverse. Their study also employed cross-sectional surveys rather than longitudinal or experimental designs, limiting causal inference about how perceptions evolve with sustained use.

Online Learning Challenges During the COVID-19 Pandemic

During the pandemic-driven shift to online learning, multiple studies documented serious engagement problems in higher education. Many students reported feelings of isolation, reduced peer interaction, and decreased motivation (Dhawan, 2020; Castelli & Sarvary, 2021). Systematic reviews have highlighted substantial variation in performance and engagement outcomes, often associated with internet quality, digital literacy, and the specific online platforms used (Adedoyin & Soykan, 2020; Bozkurt et al., 2020). Comparative studies with face-to-face classes further indicated declines in non-academic aspects, such as social presence and collaborative learning, even when overall course grades remained similar (Means et al., 2013; Hodges et al., 2020). These findings underscore that the sudden, emergency-driven transition to online education, termed emergency remote teaching, exposed both pedagogical and technological limitations in existing digital infrastructures.

The Metaverse as a Solution to Online Learning Limitations

The metaverse has been increasingly positioned by researchers as a transformative medium for education, offering interactive, avatar-mediated, and 3D-immersive environments that contrast sharply with traditional video conferencing or screen-based remote learning (Zhang, Chen, Hu & Wang, 2022). Meta-analytic and conceptual reviews highlight that avatars in educational metaverse settings can facilitate enhanced collaboration, social presence, adaptive learning, and realistic experiential tasks, contributing to higher engagement, motivation, and sense of presence among learners (Islam & Wang, 2025).

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Quantitative evidence also begins to surface: one study validating the "METAEDU" scale found that perceived ease of use and perceived usefulness significantly predict students' intention to adopt metaverse-based learning (2025). At the same time, the literature warns of persistent challenges, including technical requirements, accessibility inequalities, and the need for institutional readiness, pointing to a non-trivial trade-off between potential benefits and practical constraints (Hussain, 2023; Islam & Wang, 2025). As such, metaverse-based education can offer a middle ground: combining the immersive and social affordances of VR with the accessibility of browser- or device-based platforms mediated via avatars.

MetaKelas: Metaverse Online Class as Alternative to Current Online Class Implementation

MetaKelas is a creative online learning method to deliver lectures to students at UUM, which has been developed as an alternative way of teaching through video conferencing platforms such as Webex (Figure 3). Traditional online platforms effectively support content delivery, but they usually limit social interaction and spatial interaction among learners. MetaKelas overcomes these obstacles by using metaverse technology via the Spatial. io platform, thus standard online classes become immersive virtual learning environments that are more like physical classrooms.

Figure 3: MetaKelas Online Class

The MetaKelas environment (Figure 4) primarily focuses on avatars and spatial awareness as means of allowing learners and instructors to be in the same virtual space. Using Spatial. io, students can see their own presence and the presence and relative positioning of their peers, thus they can interact, move and communicate in a natural way during learning activities. This spatially enabled environment helps learners to feel a stronger sense of co, presence, which is a major factor in increasing engagement and decreasing the feeling of being isolated that is usually the case in conventional online learning.

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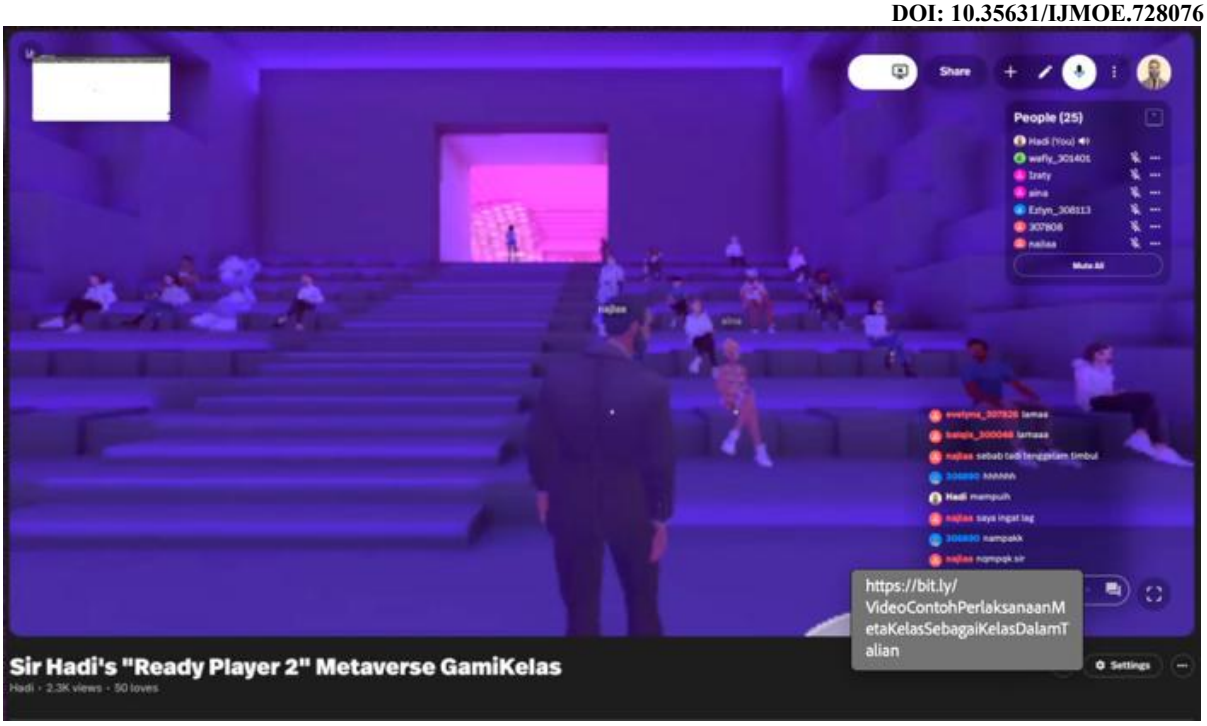

Figure 4: MetaKelas Online Class Environment

Through the reproduction of some physical classroom interaction elements, MetaKelas intends to make the student more involved and cognitively engaged during online learning sessions. The method should lead to an increase in students' attention, involvement and learning through the creation of a stronger feeling of being 'in class' whereas it is just a virtual meeting that they are attending. As a pedagogical innovation, MetaKelas is an example of how metaverse, supported educational settings can be a valuable addition to the current online teaching methods and can result in more profound and socially integrated learning experiences in higher education.

Research Gaps in TAM Application to Metaverse Learning

Despite the extensive use of TAM across various technological contexts, several critical gaps remain when applying it to metaverse-based learning. First, most TAM-based studies in education have examined relatively conventional technologies, earning management systems, educational software, mobile learning applications, rather than immersive, spatially oriented platforms that fundamentally alter how learners navigate and interact within digital environments. The cognitive and affective processes involved in adopting avatar-based virtual worlds may differ substantially from those involved in adopting productivity software. For instance, issues of digital embodiment, spatial presence, and social representation through avatars introduce dimensions not captured by traditional TAM constructs. Second, the mediating role of attitude shows inconsistent patterns across existing studies, with King and He's (2006) meta-analysis revealing considerable heterogeneity in effect sizes. This inconsistency suggests that the mechanisms linking beliefs to intentions may be context-dependent and warrant investigation in specific educational and technological settings before generalisations can be drawn.

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Consequently, existing research has not adequately distinguished among the various forms of immersive technology. Studies often conflate head-mounted display VR, augmented reality, and browser-based metaverse platforms as if they were functionally equivalent from an acceptance perspective. Yet these technologies differ substantially in accessibility, required technical proficiency, cognitive load, and social affordances. Browser-based metaverse platforms that use third-person avatars represent a scalable alternative to expensive VR systems. Yet, their effectiveness relative to both traditional video conferencing and high-immersion VR remains unexamined through the lens of technology acceptance. Fourth, most studies on educational technology adoption employ brief surveys administered at a single time point, often immediately after a demonstration or a short trial period. This methodological approach cannot capture how acceptance evolves with sustained use, how initial novelty effects dissipate, or how perceptions change as users develop proficiency with the technology.

Theoretical Framework and Study Rationale

The theoretical framework guiding this study builds directly on the TAM foundations established by Davis (1989), extended by Venkatesh and Davis (2000), and meta-analytically validated by King and He (2006). However, it applies this framework to a technological context, metaverse-based learning that differs fundamentally from the systems examined in prior research. The study investigates whether the core TAM relationships hold when the technology in question is not merely a tool for accessing information but an immersive environment that mediates social interaction, spatial navigation, and embodied presence. By examining perceived usefulness, perceived ease of use, attitude toward use, and behavioural intention within the context of MetaKelas implementation across two academic semesters, the research addresses the gap between TAM's theoretical predictions and empirical verification in immersive learning contexts.

Furthermore, this study directly tests the mediating role of attitude, which remains theoretically central to TAM but empirically inconsistent across studies. Tarhini et al. (2017) demonstrated that individual differences moderate TAM relationships, but their work did not examine whether attitude mediates the path from perceived usefulness to behavioural intention differently depending on the nature of the technology or the educational context. By employing structural equation modelling with an adequate sample size and proper mediation testing procedures, this research provides clearer evidence on whether attitude functions as a full mediator, partial mediator, or non-significant mediator in the metaverse adoption context.

Several investigations have documented that student engagement and satisfaction during online learning vary widely depending on factors such as interaction quality, technological infrastructure, and pedagogical design (Pandita & Kiran, 2023; Zulkifli et al., 2021). A systematic review covering studies from 2019–2024 found that while some online courses led to satisfactory academic performance, many students reported reduced social interaction and a sense of isolation, particularly when instructor-student and peer interactions were minimal (Discover Education, 2024). In some contexts, shifting to remote instruction during the pandemic did not result in significant differences in learning outcomes compared to face-to-face delivery, though concerns remain about non-academic aspects, including peer collaboration and academic integrity (Discover Education, 2024; Teaching in a pandemic, 2024). Other empirical work shows that their preference for face-to-face learning strongly mediated student satisfaction with online learning during COVID-19, perceived course quality,

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and ease of use of online platforms (Frontiers in Psychology, 2023). Nonetheless, some studies in higher education report moderate to high satisfaction with online modalities, particularly when courses are well designed and institutional support is adequate (BMC Medical Education, 2021; BMC Medical Education, 2023).

The practical significance of this research lies in its focus on accessible, browser-based metaverse platforms rather than high-cost VR systems. While previous research has demonstrated engagement benefits associated with immersive learning, much of this work has examined technologies that require substantial infrastructure investment, headsets, high-performance computers, dedicated physical spaces. If similar benefits can be achieved through platforms that run on standard laptops and require no specialised equipment, the implications for educational equity and scalability are considerable. Moreover, by examining sustained curricular integration rather than brief experimental interventions, this study provides evidence relevant to institutional decision-making about technology adoption. Administrators and instructional designers need to know not just whether students find a technology initially engaging, but whether acceptance and satisfaction persist over weeks and months of regular use.

This study, therefore, addresses critical gaps at the intersection of technology acceptance theory and immersive learning research. It extends TAM into a new technological domain, tests theoretical propositions about attitudinal mediation under conditions that have not previously been examined and provides practical evidence on whether accessible metaverse platforms can better maintain engagement and satisfaction than conventional video conferencing tools. The research contributes both theoretical knowledge about how acceptance mechanisms function in immersive contexts and practical knowledge about the viability of metaverse platforms as scalable solutions to persistent problems in online education.

Methodology

This study employed a quantitative, quasi-experimental, post-test-only design to investigate students' acceptance of a metaverse-based virtual classroom platform through the lens of the Technology Acceptance Model. The quasi-experimental approach was selected because it enabled examination of naturally occurring groups of students who had already been exposed to the MetaKelas (Figure 5) platform as part of their regular coursework, without requiring random assignment or artificial manipulation of learning conditions.

This design was particularly appropriate given the study's focus on measuring perceptions and behavioural intentions after sustained use of the technology in authentic educational contexts, as opposed to brief experimental exposures that might not capture how acceptance develops over time with repeated interaction. The post-test only structure enabled the collection of data at a single time point following a full semester of platform use, ensuring that participants had sufficient experience with MetaKelas to form meaningful judgments about its usefulness, ease of use, and their attitudes toward continued adoption.

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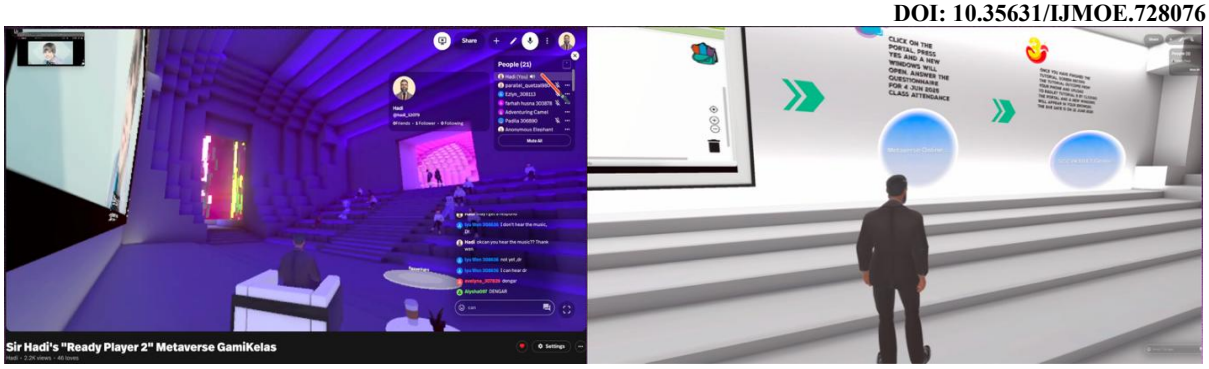

Figure 5: MetaKelas in Action

The research was conducted at UUM during two consecutive academic semesters, designated as A241 and A242, spanning approximately eight months from the beginning of the first semester through the conclusion of the second. Participants were foundation and undergraduate students enrolled in courses that used MetaKelas as the primary platform for synchronous online learning. These courses were part of the regular curriculum in the School of Multimedia Technology and Communication, where instructors had adopted the BookEnd pedagogical model to structure virtual classroom sessions.

The BookEnd model organises each learning session into three distinct phases: pre-instruction orientation, in which students are introduced to learning objectives and materials; core learning tasks, during which substantive content delivery and collaborative activities occur; and post-activity reflection, in which students consolidate their learning and provide feedback. This structured approach ensured consistency in the deployment of the metaverse platform across courses and instructors, reducing variability that might otherwise confound measures of technology acceptance.

The sample consisted of students who had completed at least one full semester of courses using MetaKelas for most of their synchronous online learning experiences. Participants were recruited through announcements made during final class sessions and through course communication channels, with participation being entirely voluntary and anonymous. No incentives were provided for participation, although students were informed that their feedback would contribute to ongoing efforts to improve the quality of online learning at the institution. The final sample included students from multiple courses to ensure diversity in disciplinary backgrounds and prior technological experience. However, all participants reported sustained MetaKelas use throughout the semester. Demographic information was collected to describe the sample but was not used to exclude participants or to stratify the sample.

Data were collected using a structured online questionnaire administered via Google Forms immediately after the conclusion of each semester's final examination period. This timing was intentional, as it allowed students to reflect on their entire semester of experience with the platform rather than providing impressions based on limited or early-stage interactions. The questionnaire was designed to operationalise the core constructs of the Technology Acceptance Model in metaverse-based learning environments. Perceived Usefulness was measured using five items adapted from Davis (1989) and Venkatesh and Davis (2000), with statements such as "Using the metaverse platform improved my learning performance" and "The metaverse platform enabled me to learn more efficiently."

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Perceived Ease of Use was similarly measured using five items, including "Learning to operate the metaverse platform was easy for me" and "My interaction with the metaverse platform was clear and understandable." Attitude Toward Use was assessed through four items capturing affective and evaluative responses, such as "Using the metaverse platform for learning is pleasant" and "I like the idea of using the metaverse platform for learning." Finally, Behavioural Intention to Use was measured using four items that tapped into future adoption plans and recommendation likelihood, including "I intend to use the metaverse platform for future learning" and "I would choose metaverse-based classes over traditional online classes."

All items were measured on a seven-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree), providing sufficient response variability to detect nuanced differences in perceptions while maintaining ease of interpretation for respondents. The questionnaire also included an open-ended section where participants could provide qualitative comments about their experiences with MetaKelas, though analysis of this qualitative data was reserved for supplementary interpretation rather than primary hypothesis testing. The survey instrument was pilot tested with a small group of students from a previous cohort to ensure clarity of wording and appropriate length, resulting in minor revisions to item phrasing before full deployment.

Data analysis was conducted using partial least squares structural equation modelling, a variance-based technique well suited to exploratory research contexts and complex models with multiple constructs (Hair et al., 2021). Several considerations justified the choice of this analytical approach. First, the study aimed to predict key target constructs, specifically Attitude Toward Use and Behavioural Intention to Use, rather than merely confirming theoretical relationships. Second, the model included both direct and mediated pathways, requiring simultaneous estimation of measurement and structural components. Third, the sample size, while adequate for the analysis, was more appropriate for variance-based methods than covariance-based structural equation modelling, which typically requires larger samples for stable estimation.

The analysis proceeded in two stages following established protocols (Hair et al., 2021). The measurement model was first evaluated to ensure that all constructs demonstrated adequate reliability and validity. Indicator reliability was assessed through outer loadings, with values above 0.708 considered acceptable. Internal consistency reliability was assessed using Cronbach's alpha and composite reliability, with thresholds of 0.70 and 0.70, respectively. Convergent validity was established through average variance extracted values exceeding 0.50, and discriminant validity was confirmed using the Fornell-Larcker criterion (Fornell & Larcker, 1981), which requires that the square root of each construct's average variance extracted exceed its correlations with other constructs.

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EISSN: 2637-0905
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DOI: 10.35631/IJMOE.728076

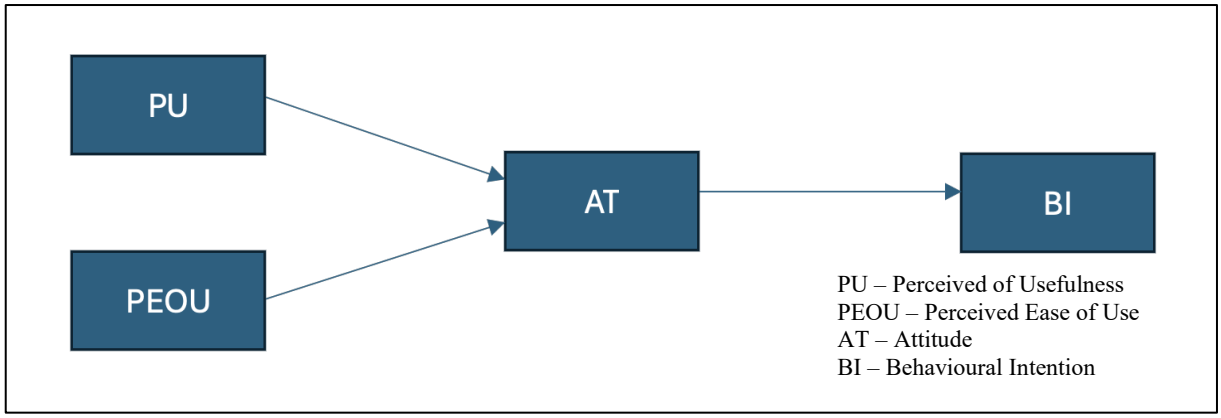

Figure 6: Structural Model

Following confirmation of measurement model adequacy, the structural model (Figure 6) was evaluated to test the study's hypotheses (Table 1). Path coefficients representing the relationships between constructs were examined for magnitude and statistical significance using bootstrapping procedures with 5,000 resamples to generate confidence intervals and significance values. The coefficient of determination was calculated for endogenous constructs to assess the model's explanatory power, with values of 0.25, 0.50, and 0.75 interpreted as weak, moderate, and substantial, respectively (Hair et al., 2021).

Effect sizes for individual paths were calculated using Cohen's f-squared statistic to determine the practical importance of relationships beyond statistical significance. Mediation effects were tested using the specific indirect effects procedure, examining whether Attitude Toward Use significantly mediated the relationships between the two belief constructs and Behavioural Intention to Use. All analyses were conducted using SmartPLS, which is designed specifically for partial least squares structural equation modelling and provides comprehensive diagnostic statistics for both measurement and structural model assessment.

Table 1: Hypothesis of The Study

	Hypothesis
H1	There is a significant relationship between Perceived Usefulness (PU) and Attitude Toward Use (AT) of the metaverse platform for teaching and learning.
H2	There is a significant relationship between Perceived Ease of Use (PEU) and Attitude Toward Use (AT) of the metaverse platform for teaching and learning.
H3	There is a significant relationship between Attitude Toward Use (AT) and Behavioral Intention to Use (BI) the metaverse platform for teaching and learning.
H4	Attitude Toward Use (AT) mediates the relationship between Perceived Usefulness (PU) and Behavioral Intention to Use (BI) the metaverse platform for teaching and learning.
H5	Attitude Toward Use (AT) mediates the relationship between Perceived Ease of Use (PEU) and Behavioral Intention to Use (BI) the metaverse platform for teaching and learning.

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Findings

Data were analysed using partial least squares structural equation modelling to evaluate both the measurement and structural models. In line with established reporting practices, the results are presented by first assessing the measurement model, then evaluating the structural relationships, and finally conducting hypothesis testing. The measurement model demonstrated satisfactory reliability and validity across all constructs. As presented in Table 2, all indicator loadings exceeded the recommended threshold of 0.708, ranging from 0.827 to 0.973, indicating strong indicator reliability and confirming that each item adequately represented its respective latent construct. Internal consistency reliability was further assessed using Cronbach's Alpha and Composite Reliability. As shown in Table 3, Cronbach's Alpha values ranged from 0.937 to 0.970, while Composite Reliability values ranged from 0.955 to 0.977.

These values exceed the recommended minimum criteria, indicating a high level of internal consistency across all constructs in the model. Convergent validity was evaluated using the Average Variance Extracted (AVE). The AVE values reported in Table 3 ranged from 0.814 to 0.893, exceeding the recommended threshold of 0.50 and indicating that each construct explained a substantial proportion of variance in its indicators. Discriminant validity was assessed using the Fornell–Larcker criterion. As presented in Table 4, the square root of the AVE for each construct was greater than its correlations with other constructs, thereby supporting adequate discriminant validity.

Table 2: Outer Loadings

Construct	Item	Outer Loading
PU1	Using the metaverse platform improved my learning performance	0.932
PU2	Using the metaverse platform enhanced my learning effectiveness	0.95
PU3	The metaverse platform made it easier to accomplish learning tasks	0.955
PU4	I found the metaverse platform useful for my education	0.963
PU5	The metaverse platform enabled me to learn more efficiently	0.941
PEU1	Learning to operate the metaverse platform was easy for me	0.827
PEU2	I found it easy to get the metaverse platform to do what I wanted	0.848
PEU3	My interaction with the metaverse platform was clear and understandable	0.918
PEU4	I found the metaverse platform flexible to interact with	0.936
PEU5	It was easy for me to become skilful at using the metaverse platform	0.948
AT1	Using the metaverse platform for learning is a good idea	0.863
AT2	Using the metaverse platform for learning is pleasant	0.898
AT3	I like the idea of using the metaverse platform for learning	0.961
AT4	Using the metaverse platform for learning is interesting	0.973
BI1	I intend to use the metaverse platform for future learning	0.85

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BI2	I would recommend the metaverse platform to other students	0.892
BI3	I plan to continue using metaverse platforms for education	0.942
BI4	I would choose metaverse-based classes over traditional online classes	0.959

Table 3: Construct Reliability and Validity

Construct	Cronbach's Alpha	Composite Reliability	AVE
PU	0.97	0.977	0.893
PEU	0.942	0.956	0.814
AT	0.952	0.966	0.876
BI	0.937	0.955	0.842

Table 4: Fornell-Larcker Criterion

Construct	AT	BI	PEU	PU
AT	0.936	0.877	0.789	0.848
BI		0.918	0.861	0.906
PEU			0.902	0.86
PU				0.945

Following confirmation of the measurement model, the structural model was evaluated to assess the proposed hypotheses. The coefficient of determination values indicates substantial explanatory power, with R^2 values of 0.733 for Attitude Toward Use and 0.769 for Behavioural Intention to Use, as reported in Table 5. The results of hypothesis testing, summarised in Table 6, show that Perceived Usefulness had a significant positive effect on Attitude Toward Use ($\beta = 0.650$, $p = .005$), supporting H1.

In contrast, Perceived Ease of Use did not have a significant effect, thereby rejecting H2. Attitude Toward Use had a strong and significant effect on Behavioural Intention to Use ($\beta = 0.877$, $p < .001$), supporting H3. Mediation analysis further revealed that Attitude Toward Use significantly mediated the relationship between Perceived Usefulness and Behavioural Intention to Use ($\beta = 0.570$, $p = .005$), supporting H4. In contrast, no significant mediation effect was observed for Perceived Ease of Use, thereby rejecting H5. Effect size analysis reported in Table 5 indicates a significant impact of Perceived Usefulness on Attitude Toward Use ($f^2 = 0.413$), a small impact of Perceived Ease of Use on Attitude Toward Use ($f^2 = 0.052$), and a considerable effect of Attitude Toward Use on Behavioural Intention to Use ($f^2 = 3.336$).

Table 5: Coefficient of Determination and Effect Size

Endogenous Construct	R^2	f^2 (PU → AT)	f^2 (PEU → AT)	f^2 (AT → BI)
AT	0.733	0.413	0.052	
BI	0.769			3.336

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Table 6: Hypothesis Testing Results (Pls-Sem)

Hypothesis	Path	β (Beta)	t-value	p-value	Result
H1	PU → AT	0.65	2.798	0.005	Supported
H2	PEU → AT	0.23	1.04	0.298	Not Supported
H3	AT → BI	0.877	24.444	0.0	Supported
H4	PU → AT → BI	0.57	2.785	0.005	Supported
H5	PEU → AT → BI	0.202	1.031	0.303	Not Supported

The overall pattern of relationships is visually illustrated in Figure 7, which presents the measurement and structural model evaluation. The figure depicts the direction and relative strength of the estimated paths among the constructs, visually reinforcing the dominance of the relationship between Attitude Toward Use and Behavioural Intention to Use, as well as the greater influence of Perceived Usefulness than Perceived Ease of Use in shaping students' attitudes. These visual patterns are consistent with the statistical results reported in Tables 2 to 6.

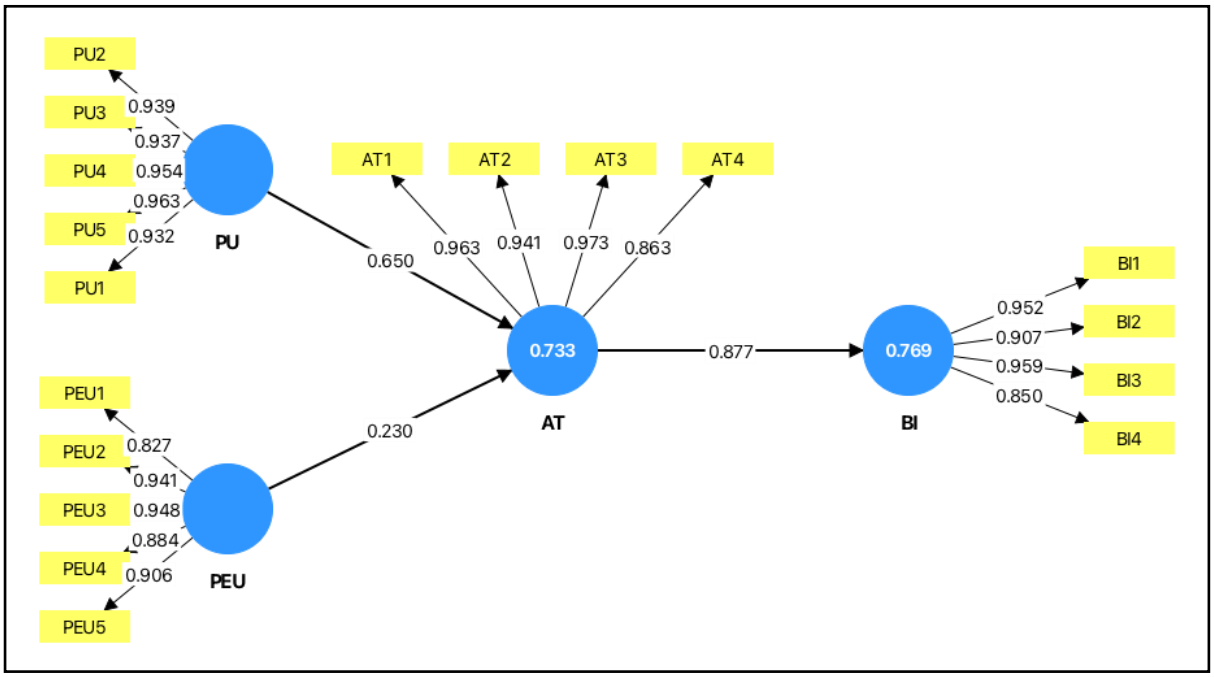

Figure 7: Measurement Model and Structural Model Evaluation

Implications

Theoretical Implications

This study offers several important theoretical implications for research on technology acceptance in immersive learning environments. By applying the Technology Acceptance Model to a browser-based metaverse learning platform, the findings extend TAM's applicability beyond conventional learning management systems and video conferencing tools. While TAM has been widely validated across educational technologies, its use in avatar-based, spatially mediated learning contexts remains limited. The present study demonstrates that the core structure of TAM remains robust in immersive environments, but the relative importance of its constructs shifts in meaningful ways.

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One key theoretical contribution lies in the dominant role of perceived usefulness in shaping students' attitudes toward metaverse learning. The findings indicate that students evaluate immersive platforms primarily based on their perceived contribution to learning effectiveness, engagement, and interaction, rather than on interface simplicity. This suggests that in immersive educational contexts, usefulness may encompass not only instrumental efficiency but also experiential and pedagogical value. From a theoretical perspective, this extends the conceptual interpretation of perceived usefulness within TAM to immersive, socially rich learning environments.

In contrast, perceived ease of use did not significantly influence attitude toward use. These finding challenges early assumptions within TAM that ease of use consistently functions as a primary antecedent of attitude. Instead, the results support more recent perspectives suggesting that among digitally fluent users, usability may be perceived as a baseline expectation rather than a differentiating factor. Theoretically, this implies that in contexts in which learners are accustomed to navigating complex digital interfaces, perceived ease of use may play a secondary role once a minimum usability threshold is met. This nuance contributes to ongoing theoretical refinement of TAM by highlighting the contextual sensitivity of its constructs.

The strong relationship between attitude toward use and behavioural intention further underscores the importance of affective and evaluative mechanisms in technology acceptance within immersive learning settings. Unlike traditional online platforms that primarily facilitate content transmission, metaverse environments provide experiential and social affordances that shape learners' emotional responses. The findings suggest that attitude functions as a central psychological mechanism through which cognitive evaluations are translated into adoption intentions. This reinforces the mediating role of attitude proposed in TAM and demonstrates its heightened relevance in immersive and interactive learning environments.

Finally, the mediating effect of attitude in the relationship between perceived usefulness and behavioural intention offers theoretical insight into the processual nature of technology acceptance. Rather than directly driving intention, perceived usefulness influences adoption by fostering favourable attitudes toward the learning environment. This finding highlights the importance of examining indirect pathways within acceptance models, particularly in emerging educational technologies where experiential factors play a significant role. Collectively, these theoretical implications suggest that while TAM remains a valuable framework, its application to metaverse-based learning requires careful attention to contextual affordances, learner characteristics, and the evolving nature of digital learning experiences.

Practical Implications

The findings of this study provide several practical implications for educators, instructional designers, and higher education institutions seeking to implement metaverse-based learning environments. The results suggest that students' adoption of immersive learning platforms is driven primarily by perceived educational value rather than by interface simplicity. Accordingly, practical efforts should prioritise pedagogical design and learning outcomes over purely technical considerations.

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For educators, the findings highlight the importance of aligning metaverse activities with clear learning objectives. Metaverse platforms should not be used merely as alternative delivery spaces, but as environments that support interaction, collaboration, and experiential learning. Teaching strategies should emphasise how immersive features such as avatars, spatial navigation, and virtual interaction enhance understanding, engagement, and participation. Early learning activities play a particularly important role, as positive initial experiences contribute to the formation of favourable attitudes toward continued use.

For instructional designers, the results suggest that usability alone is insufficient to ensure adoption. While basic operability remains essential, design efforts should focus on creating meaningful learning experiences that demonstrate clear pedagogical benefits. Structured instructional models, such as staged activities, guided interaction, and reflective tasks, can help students recognise the value of immersive learning environments. Visual coherence, intuitive navigation, and consistent interaction mechanics should support learning rather than dominate design priorities.

At the institutional level, the findings offer guidance for strategic decision-making related to educational technology adoption. Browser-based metaverse platforms present a scalable and accessible alternative to hardware-intensive virtual reality systems, reducing barriers related to cost, infrastructure, and technical expertise. Institutions may consider integrating such platforms into blended or online curricula as complementary tools rather than full replacements for existing learning management systems. Providing appropriate orientation, technical support, and pedagogical guidelines can further enhance students' acceptance and sustained use of metaverse learning environments.

Overall, these practical implications suggest that successful implementation of metaverse-based learning depends less on technological novelty and more on thoughtful pedagogical integration. By emphasising learning value, meaningful interaction, and structured instructional design, educators and institutions can better leverage immersive platforms to enhance online learning experiences in post-pandemic higher education.

Future Research Direction

While this study provides empirical insights into students' acceptance of browser-based metaverse learning, several directions for future research may further advance understanding in this area. First, future studies could examine the applicability of the proposed model across different institutional contexts, academic disciplines, or levels of education. Investigating diverse learning settings would help determine whether the observed relationships remain consistent beyond the current sample and context.

Second, future research may explore the inclusion of additional psychological or experiential constructs to enrich existing acceptance models. Variables related to social presence, immersion, engagement, or collaborative experience may provide deeper insight into how learners evaluate and respond to immersive learning environments. Such extensions help clarify the role of experiential factors that are not fully captured within traditional technology acceptance frameworks.

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EISSN: 2637-0905
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Third, longitudinal research designs could be employed to examine changes in students' attitudes and behavioural intentions over time. As familiarity with metaverse platforms increases, perceptions of usefulness, ease of use, and overall acceptance may evolve. Longitudinal approaches would allow researchers to assess whether initial adoption intentions translate into sustained use and learning outcomes.

Finally, future studies could adopt mixed-method or experimental designs to complement survey-based findings. Qualitative approaches such as interviews or focus group discussions may provide richer insight into students' lived experiences within metaverse environments, while experimental designs could examine the causal impact of specific instructional strategies or design features on learning engagement and performance. Collectively, these directions highlight opportunities for continued theoretical and empirical development in metaverse-based learning research, particularly as immersive technologies become more integrated into mainstream higher education.

Conclusion

This study examined students' acceptance of a browser-based metaverse learning platform using the Technology Acceptance Model. The findings demonstrate that perceived usefulness plays a central role in shaping students' attitudes toward metaverse learning, which in turn strongly influences their behavioural intention to continue using the platform. Attitude also mediates the relationship between perceived usefulness and behavioural intention, underscoring its importance as a key psychological mechanism in the adoption of immersive learning. In contrast, perceived ease of use played a limited role in shaping students' attitudes, suggesting that usability alone is insufficient to drive acceptance among digitally fluent learners.

These findings contribute to a more nuanced understanding of technology acceptance in immersive educational contexts. By extending the application of TAM to a browser-based metaverse environment, the study provides evidence that the model remains relevant. However, the relative importance of its constructs may shift with contextual affordances and learner characteristics. The results underscore the importance of perceived pedagogical value and experiential quality in shaping learners' responses to emerging educational technologies.

From a broader perspective, the study underscores the relevance of metaverse-based learning beyond emergency remote teaching. Browser-based immersive platforms offer a scalable and accessible alternative for higher education institutions seeking to enhance online learning experiences without the infrastructural constraints associated with hardware-intensive virtual reality systems. When integrated thoughtfully into instructional design, such platforms can support sustained engagement and meaningful learning interactions in post-pandemic online education.

Overall, this study provides theoretical and practical insights into how immersive learning environments can be effectively adopted in higher education. By emphasising the central role of perceived usefulness and attitude, the findings offer guidance for future research and implementation efforts aimed at maximising the educational value of metaverse-based learning.

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Acknowledgements

The authors would like to acknowledge and extended special gratitude to the School of Multimedia Technology and Communication, Universiti Utara Malaysia, who granted the permission and academic support on doing this project.

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