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The Effectiveness of Gamified Augmented Reality in Higher Education: A Case Study of MARA 5.0 in a Public University

*Abdul Hamid Abdul Halim[1], Dr Hairulnizam Hashim[2], Masrur Mohd Khir[1], Nor Azzura Nordin[1], Ryan Kang Jee Hong[3], Natalie Loi Yoke Kei[3]
[1]Department of International Business and Management Studies, Universiti Teknologi MARA, Malaysia
[2]Department of Economics and Financial Studies, Universiti Teknologi MARA, Malaysia
[3]Unbound Malaysia Sdn. Bhd., Malaysia
Email: *abdulh2949@uitm.edu.my, hairul1927@uitm.edu.my, masrur@uitm.edu.my, azzura344@uitm.edu.my, ryank@unboundmalaysia.com, nataliel@unboundmalaysia.com
Corresponding Author: Abdul Hamid Abdul Halim

Abstract: This study aims to determine the impact of an augmented reality (AR) game on students' learning experience. The effects of the AR game Mission AR Apocalypse (MARA) 5.0 on students' learning experiences at Universiti Teknologi MARA (UiTM) were assessed. A survey of 750 students was conducted before and after playing the game in June 2024. There were seven dimensions of learning evaluated. Scores significantly increased after the intervention across all areas of learning. The highest increase was in conceptual understanding (mean 2.41 to 4.39), followed by learning motivation (2.23 to 3.93). The results indicate that initial technology-related difficulty was manageable. The findings imply that AR can improve understanding and motivation, but further implementation requires broadening use in challenging subjects, targeted training, and equal access to the devices needed. The results indicate that AR can be used in higher education to support active learning. In many cases, this requires overcoming barriers to usability for students and instructor resistance. The barriers can hinder learning in complex topics.

Keywords: *Augmented reality (AR) games; player satisfaction; immersive experience; post-event behaviour; game design and engagement*

1. Introduction

With all this in mind, we have seen the conversation shift toward looking at ways to innovate in education, particularly through technology (Lampropoulos, 2025). The field of Augmented Reality (AR) has been identified as one of the best places to start, providing a real-world connection between theory and practice. With AR, students no longer need to simply read textbooks or listen to lectures; they can be immersed in an extremely engaging, interactive environment where everything is put to work. As one can imagine, traditionally university students are spoon-fed a diet of textbooks, lectures and maybe some practical labs here and there. While perfectly serviceable for many purposes, they are not always well equipped to help all students digest highly complex concepts or even just the more abstract concepts.

A general lecture may fail to engage visual or kinesthetic learners, which can become problematic in disciplines like science, technology, engineering and math where spatial reasoning and visualization are essential (Pireva & Shatri, 2026). AR steps up to the plate and fills this gap. Trials recently showed that students who learned in an AR-enabled classroom were generally performing better, stayed interested longer and actually understood the content on a much deeper level (Arsyad, Apriansyah, Awaludin, Khasanah & Prasetyo, 2025). Whether students are able to hold it in their hands and turn it around remains an open question. Immediately the cognitive load is lowered. What makes things easier is that improved comprehension of instructional materials is only one of the benefits of using augmented reality (AR), since the addition of fun could also conceivably help memory retention via greater attention and longer periods of engagement. It is not so much about making something new as about structuring the experience of the learner through the use of AR. That is, placing information in a visually meaningful, spatially organized format and prompting them to actively explore may decrease the sense of effort involved in studying and encourage learners to sustain their focus for longer. This is probably dependent on the design decisions made, for instance, if the AR elements are tied to the learning objectives, or if they draw attention away from the focus material.

It is also often touted that AR can accommodate different learning styles at once. For those who require visual stimuli, AR can offer vibrant and spatial representations of concepts that make the relations clearer. This

includes aspects like size, distance, orientation, etc., which are harder to express in static diagrams. For those who are kinesthetic learners, AR can be used to enable learning through represented interactions, for instance, via moving digital objects with hand gestures, moving models around in the environment, or triggering content based on movement. These different modalities could overlap, whereby learners see and act on the same representation, perhaps associating what they see with what they do and what they say. Whether these overlapping modalities are effective will depend on the situation, including the difficulty of the subject matter, the level of the learner, and how easy it is to interact with. As the technology develops rapidly, we can now quantify the impact it has quite easily. Current research certainly seems to imply that game-based AR can indeed drive an educational revolution, improving not only test scores, but important problem-solving skills too (Li, Luo, Chen, Wang, Yin & Zhang, 2025). The systematic review highlights that AR always yields a large, positive effect on instructional quality and real learning outcomes in higher education (Takona, 2024)

Mission AR Apocalypse 5.0 is an augmented reality game created for students at Universiti Teknologi MARA. The game was co-developed by UnBound Malaysia and Event Management students at the university, and it was initially released during the 2021 COVID-19 lockdown. It is now in its fifth iteration. In alignment with the Malaysia Education Blueprint and the Higher Education Digitalisation Agenda, Malaysian public universities are also accelerating their digital transformation to better equip graduates to enter a high-tech economy. As part of the national initiatives of MyDIGITAL (Economic Planning Unit [EPU], 2021a), the National 4IR Policy (EPU, 2021b), and Education 5.0, higher education institutions need to adopt a new teaching and learning model to focus on student-centered active learning via interactive technologies that can decrease the cognitive load while enabling the learning of spatial orientation and critical thinking skills, including solving real-world problems.

Problem Statement

While there is growing adoption of AR in higher education, few studies have evaluated the long-term effectiveness of this new teaching and learning modality. The technology is still relatively new and often viewed as a 'novelty' by educators and students, rather than an essential instructional methodology. AR is therefore seldom applied in a manner that truly taps into its potential as an effective instructional platform. University students also often suffer from a knowledge-action gap, especially in fields like STEM and financial literacy. Students are taught basic theoretical concepts, but conventional educational strategies may not be able to support hands-on implementation and lifelong self-confidence. Traditional university teaching practices still revolve around 'dead' textbooks and one-way lecturing. Existing research indicates that these passive teaching strategies cannot cater to the diverse learning styles of the student population and could lead to boredom and diminished levels of self-motivation to learn, resulting in an elevated mental workload when confronting abstract ideas. This practical knowledge gap is specifically pronounced in fields like financial literacy and business management. Young people tend to know in theory how to save and invest money. Yet they often get confused when faced with actual financial choices. This represents a classic example of the 'knowledge-action gap' (Yong, Yew & Wee, 2018). Financial awareness among young Malaysians is essential for their long-term welfare (Yaacob, Zainuddin & Rohani, 2024). Most of the extant AR education research consists of individual case studies or specific subjects, which sheds no light on how immersive technology can be used to fill these exact behavioral knowledge gaps. We do know from some early studies that AR, specifically if combined with game elements, is highly effective in capturing students' attention (Kodirova, 2025). However, we still do not know enough about its effects on critical thinking, problem-solving, and long-term knowledge retention. We also do not know enough about how different groups of students respond to AR to help us customize it to serve their varied learning needs.

While augmented reality and mobile immersive technologies are being increasingly deployed in university teaching settings, there is a lack of empirical work that helps us to understand how they impact student learning. Much of the existing literature examines small-scale case studies or focuses on specific disciplines. This means we do not yet have a strong understanding of how gamified augmented reality impacts large cohorts of students in public universities, especially with respect to their ability to comprehend concepts, motivation, and confidence in their abilities. This may be part of the reason why people tend to see them more as a novelty than a serious learning tool. Because there is already an overall movement toward greater digitalization in higher education, it makes sense to assess the efficacy of gamified augmented reality systems in a more empirical way, to both allay concerns about their utility, support university investments in new

technology, and offer evidence-based advice about how best to use immersive platforms to teach students across a broad range of disciplines as part of the mainstream curriculum.

Research Objectives

This study evaluates the overall pedagogical effectiveness of a gamified augmented reality (AR) system in enhancing the learning experience of university students. Specifically, the research aims to:

- Assess the impact of gamified AR on student conceptual comprehension and knowledge retention in complex subject areas compared to traditional learning methods.
- Measure changes in student learning motivation, active material engagement, and interactivity following the implementation of the AR system.
- Evaluate post-intervention shifts in student academic self-efficacy, adaptation across the technological learning curve, and overall educational satisfaction.

2. Literature Review

Traditional Learning Techniques vs. Technologies such as AI and AR

The debate over how to best integrate advanced tools like AI and AR into conventional classrooms has dominated recent educational development (Lampropoulos, 2025). For centuries, formal education has leaned heavily on textbooks, lectures, and rote memorization. While reliable, these methods often struggle to accommodate diverse learning styles or foster deep, experiential understanding.

Traditional learning methods: The education system has always been based on textbooks and lectures. They have served us well for hundreds of years, and it is easy to see why. A textbook is a perfect reference tool that one can come back to. And a teacher can broadcast the information to thousands at once through a lecture. It is cost-effective, easy to scale, and supported by an enormous amount of research over hundreds of years. The problem is that textbooks and lectures support passive learning. One just sits there like a sponge soaking up knowledge. This often kills motivation and makes it difficult to retain what one learned. Even worse, most students do not know how to translate theory into practice when they apply it to their jobs or everyday life (Arteaga, Biesbroek, Nalau & Howes, 2024). And a standard lecture cannot simultaneously cater to visual, auditory, and kinesthetic learners, so comprehension gaps naturally occur (Lampropoulos, 2025).

Advanced Technologies: AI and AR are more dynamic and extremely personalized. With AI, instructional differentiation can be taken to another level. Adaptive learning platforms analyze real-time performance and make pacing and content decisions on the fly based on the individual learner's performance gap (Mosha, Chigwada, Ketchiwou & Ngulube, 2026). The personalization cuts down learning deficits tremendously. A systematic review of the role of AI in blended learning in higher education in 2025 revealed that 85.1% of studies reported statistically significant gains in academic achievement, while there was also a 78.7% increase in engagement (Hoogers, Thüring & Michels, 2026). AR is different. It adds virtual content to the physical world. Students can play with 3D objects, go through virtual experiences, and interact with the course in ways not possible before.

Interactivity: Traditional Education Methods vs. AR/AI Technologies

Traditional Education Methods: While dominant, traditional methods offer incredibly low interactivity. The one-way flow of a standard lecture rarely allows for meaningful conceptual exchange, turning what should be an active discussion into a passive case presentation (Beigzadeh, Bazyar, Delzendeh, Razmi & Sharifi, 2024; Boedeker, Schlingmann, Kailin, Nair, Foldes, Rowley, Salciccioli, Maag, Moreno & Ismail, 2025). Textbooks operate the same way; students read and absorb with zero opportunity for active, guided problem-solving.

Augmented Reality (AR) and Business Simulations: This is the passive model that AR shatters. It allows students to bring their ideas to life by combining digital content with real spaces. With AR, students can engage in interactive simulations that allow them to experiment, fail, and learn freely in a completely safe, consequence-free environment. Game-based learning interventions are indicating remarkable results when applied to financial literacy. They boost intrinsic motivation by wrapping complex financial decisions in an engaging story. They also actively discourage behavioral biases such as risky herd behavior or overconfidence (Kosasih & Juhana, 2025). Gamified tools rooted in Human-Computer Interaction (HCI) principles use

immediate feedback loops to successfully guide users through tricky budgeting constraints (Yulianto, Pramono, Wijaya & Nasrun, 2024).

Collaborative Learning with AI and AR: Both technologies excel at fostering teamwork. AI can analyze student profiles to build perfectly balanced groups with complementary skills. Meanwhile, AR provides shared digital spaces where geographically dispersed students can interact and collaborate on 3D models in real-time (Ramli, Mohamad, Kassim, & Puspita, 2025).

Familiarity Problems in Traditional Education Methods Vs. AR/AI Technology

Understanding Traditional Teaching Methods: Despite their flaws, traditional methods have one massive advantage: familiarity. Having been exposed to textbooks and lectures since childhood, both students and educators know exactly what to expect. This predictability dramatically lowers classroom anxiety, allowing students to focus entirely on the subject matter rather than fumbling with a new technological format (Digital Education Council, 2026).

The Technology Acceptance Model (TAM) and Educator Expectations: The Technology Acceptance Model (TAM) suggests that if a person thinks a system is useful and easy to use, then they will adopt it. This perceived ease of use takes a large hit as many teachers have never even heard of AR and AI before, let alone had an opportunity to learn about them. Unlike passing out a syllabus, it takes serious knowledge and effort to implement AR (Davis, 1989). Modern TAM analyses also reveal another aspect: AI anxiety. Faculty and students may be concerned about data privacy, algorithmic bias, and academic integrity issues, which makes them reluctant to wholly embrace this technology. An international survey discovered that although students frequently employ AI, there are several who think it does not genuinely help them better comprehend the material, which proves that transparency and functionality rather than technological novelty are necessary for long-term acceptance (Digital Education Council, 2026).

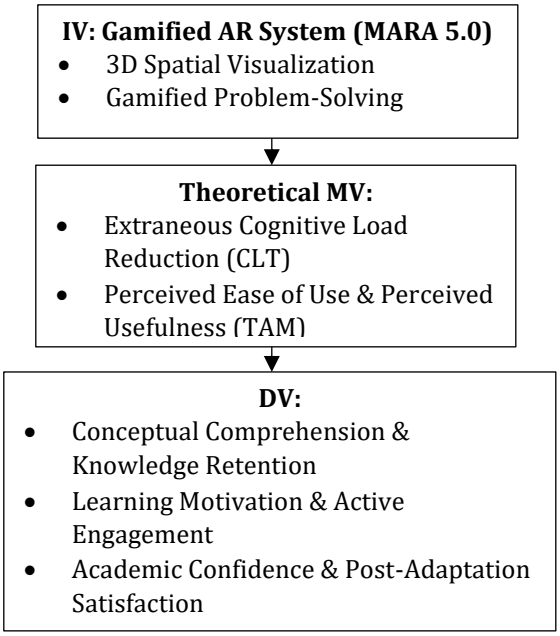
Resistance to Change

Traditional institutions are resistant to AR and AI, mostly because of the high start-up costs of the headsets, weak campus Wi-Fi and the large headache associated with revamping existing curricula. The main problem with adopting AR in the classroom is that research shows that university leadership is concerned about the risks involved. Studies in technology acceptance and use (TAM) and unified theory of acceptance and use of technology (UTAUT) suggest that faculty are often fearful that AI will completely disrupt their teaching style or even worse, it could threaten their future career prospects (Tomovic & Tomovic, 2025). They are also concerned about data privacy and a lack of clear AI governance (Weis, Bele & Erčulj, 2026). For cash-strapped universities, the financial pressure of constantly updating technology leads to university leaders refusing to invest in tools that they do not think they can sustain (Garzón, Patiño & Marulanda, 2025). To combat resistance, universities must not only convince faculty that AR actually works but also ease faculty fears via transparent governance. Faculty who are terrified about AR tools automating their tasks need comfort and thorough training (Al Issa & Maheshwari, 2026). There is no quick fix to rolling out AR; it needs a broad approach, which includes smooth user experience design, broad staff training and specific measures designed to lower instructor fears. And when an institution has a culture that values traditional exams as a means of assessment, there is often a lack of buy-in from administration for a new method like AR.

Theoretical Framework

We combine Cognitive Load Theory (CLT) (Sweller, 1988) and the Technology Acceptance Model (TAM) (Davis, 1989) to show the effectiveness of gamified AR in terms of learning outcomes (Figure 1). These outcomes will ultimately result in post-adaptation satisfaction (Abdul Halim, Mohd Khir, Kang & Loi, 2024). According to CLT, humans have a limited working memory. Students often experience high extraneous cognitive load in traditional lectures because they are required to visualize complicated abstract 3D concepts using 2D media. On the other hand, gamified AR effectively reduces the extraneous cognitive load because it maps digital objects into the real 3D world so that working memory can easily process complex structures. According to TAM, individuals decide to adopt a new technology based on its Perceived Ease of Use (PEOU) and Perceived Usefulness (PU). Gamified AR can increase the PU and PEOU by incorporating interactive game mechanics that foster intrinsic learning motivation, active learning, and academic self-efficacy after adaptation.

Figure 1:Theoretical Framework



Hypothesis

Based on the discussion of the differences between traditional education methods and the use of AR/AI technologies, here are three hypotheses that could be explored in relation to the before and after effects of using AR in education:

H1: By reducing extraneous cognitive load through 3D spatial visualization, students using the gamified AR system will demonstrate significantly higher conceptual comprehension and retention of complex topics compared to traditional learning methods.

H2: Rooted in the Technology Acceptance Model, the interactive and gamified elements of the AR system will significantly increase students' perceived usefulness and intrinsic learning motivation compared to passive lecture-based instruction.

H3: As students overcome the initial technological learning curve, increased perceived ease of use will lead to statistically significant improvements in academic self-efficacy, overall educational satisfaction, and confidence post-intervention.

3. Methodology

The study utilized a repeated-measures design, capturing data through an initial baseline survey and a follow-up survey after the completion of the AR game. The cohort comprised 750 undergraduate and postgraduate students. The demographic breakdown is as follows:

Gender: Women (57%, n = 428); Men (43%, n = 322).

Age Profile: The sample is heavily concentrated around traditional university ages, with 19–20-year-olds constituting over half the cohort (Below 18: 11%; 18: 18%; 19: 27%; 20: 25%; 21: 12%; 22 and above: 7%).

Sampling and Participant Selection

Students participated voluntarily after giving their digital informed consent prior to completing the baseline survey. Data anonymity and data protection protocols were followed for a 45-day secure data retention period. The students were recruited through a purposive sampling method where they participated in the Mission AR Apocalypse (MARA) 5.0 event held at Universiti Teknologi MARA (UiTM). Inclusion criteria consisted of currently enrolled university students who were actively using the MARA 5.0 AR modules during the event time frame in June 2024. A total of n = 750 students participated in this study.

Instrumentation and Reliability

A 12-item questionnaire with 5-points on a Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree) was used as a research tool. The content validity of this questionnaire was checked through the opinions of experts who were educated in the field of educational technology. To determine the reliability of the construct, Cronbach's alpha (α) was used. In addition to obtaining high reliability (α = 0.82), Cronbach's alpha (α) in the pretest (0.82) and after the intervention (0.86) was higher than the acceptable value in academic studies (0.70).

Statistical Analysis

Data were analyzed using SPSS statistical software. To account for the within-subject, repeated-measures research design, a Paired-Samples t-Test was conducted to evaluate mean score differences across all pedagogical dimensions pre- and post-AR intervention. Statistical significance was set at an alpha level of 0.05. Practical significance was evaluated using Cohen's d to determine effect sizes.

4. Results

Here is the formatted statistical difference test result table based on the analysis of the 750 surveyed students:

Table 1: Paired-Samples t-Test (N = 750, df = 749)

Core Pedagogical Dimension	Pre-AR Mean (SD)	Post-AR Mean (SD)	Mean Shift (ΔM)	t-Statistic (df=749)	p-Value	Cohen's d (Effect Size)
Material Engagement	2.76 (1.01)	3.79 (0.98)	+1.02	19.88	< 0.001	1.03 (Large)
Interactivity	3.05 (1.26)	3.85 (0.91)	+0.80	14.09	< 0.001	0.73 (Medium-Large)
Conceptual Comprehension	2.41 (0.81)	4.39 (0.83)	+1.98	46.76	< 0.001	2.41 (Extremely Large)
Learning Motivation	2.23 (0.92)	3.93 (0.97)	+1.71	34.92	< 0.001	1.80 (Extremely Large)
Teaching Effectiveness	3.21 (1.12)	3.47 (1.13)	+0.27	4.55	< 0.001	0.24 (Small)
Academic Confidence	3.06 (0.95)	3.33 (1.09)	+0.26	5.02	< 0.001	0.26 (Small)
Overall Satisfaction	3.34 (0.98)	3.59 (1.14)	+0.25	4.48	< 0.001	0.23 (Small)

Table Interpretation Key

The core statistical metrics in the results tables evaluate the significance, magnitude, and practical impact of the AR intervention (Table 1):

t-Statistic: Measures the size of the score difference relative to the variation within the student sample. An absolute value of $t > 1.96$ indicates statistical significance at the 95% confidence level ($\alpha = 0.05$).

p-Value: Represents the probability that an observed shift occurred purely by random chance. A value below 0.05 (or < 0.001) confirms the results are statistically significant, allowing for the rejection of the null hypothesis.

Mean Shift (ΔM): Shows the exact numeric change between baseline (pre-AR) and follow-up (post-AR) average scores on the 1–5 Likert scale.

Cohen's d (Effect Size): Measures the practical strength or real-world impact of the AR tool, independent of sample size (0.2 = small, 0.5 = medium, 0.8+ = large/substantial).

Core Statistical Insights

Absolute Rejection of the Null Hypothesis (H0): For each of the 7 core pedagogical aspects tested, the p-values are extremely low, which suggests that it is unlikely that the improvements we see are due to chance variation.

Substantial Effect Sizes in Comprehension & Motivation: The t-statistics for Conceptual Comprehension ($t = 46.760$) and Learning Motivation ($t = 34.920$) are high. This is an indication that there has been a fundamental change in the students.

Validation of Marginal Shifts: Even though the mean shifts, such as Institutional Teaching Effectiveness (+0.27) and Academic Confidence (+0.26), look trivial, the t values (4.555 and 5.020) indicate that these changes are statistically significant and are worth noting, particularly when the sample size is so large (N = 750).

Discussion

The statistical results strongly support all three of the researchers' hypotheses, proving that the MARA 5.0 AR game successfully transformed the students' educational experience. All tested dimensions yielded a p-value of <0.001, allowing for an absolute rejection of the null hypothesis across the board.

Hypothesis 1: Understanding and Retention

This metric saw the most profound transformation in the entire study. The baseline mean for comprehension was incredibly low at 2.41, but post-AR implementation, it skyrocketed to 4.39. The mean shift of +1.98 combined with an exceptionally high t-statistic (46.760) confirms that H1 is absolutely validated. AR clearly succeeded in making complex concepts more understandable than traditional methods.

Hypothesis 2: Engagement and Motivation

Learning Motivation experienced a massive effect size, jumping from a frustrated baseline of 2.23 to 3.93 (+1.71 shift, t=34.920). Similarly, Material Engagement rose from 2.76 to 3.79 (+1.02 shift, t=19.882), and Interactivity improved by +0.80. The massive t-statistics and positive mean shifts verify H2. Moving away from a frustrating baseline environment, the gamified AR system successfully pulled the student population distribution into an overwhelmingly positive and motivated learning zone.

Hypothesis 3: Adaptation and Satisfaction

While the mean shifts for these metrics are smaller (Overall Satisfaction +0.25, Academic Confidence +0.26, Teaching Effectiveness +0.27), they are fully verified as real improvements driven by the large sample size of 750 students. These marginal but highly significant positive shifts support H3. Despite any initial unfamiliarity or learning curve, the post-AR scores prove that students adapted well, resulting in statistically verifiable increases in their overall academic confidence and satisfaction with the teaching method ($p<0.001$).

Summary of Empirical Findings

Our results show that MARA 5.0 does influence how students learn complex concepts. There was a large shift in conceptual understanding ($\Delta M = +1.98$, $d = 2.41$) due to the impact of 3D spatial visualization on cognitive processing. According to Cognitive Load Theory (Sweller, 1988), it makes sense to replace a static 2D diagram with an interactive spatial model, as it will reduce extraneous cognitive load, which allows for more efficient working memory capacity to be applied towards core concepts. Our results are consistent with other studies (Pireva et al., 2026; Li et al., 2025) that imply that spatial immersion leads to faster acquisition of concepts within complex topics.

From the perspective of motivation, confidence, and the tech curve, the presence of gamification elements increased learning motivation ($\Delta M = +1.71$, $d = 1.80$) because they helped to meet the needs for autonomy and competence, as posited by Davis (1989). It is possible that some students may have entered into a flow state, where their actions become intrinsically motivated, as described previously. The impact on academic confidence ($\Delta M = +0.26$, $d = 0.26$) was not as significant as on motivation.

Because students need to feel in control of the new technology in order to develop real self-efficacy, they need to gain experience using it repeatedly so that their confidence builds up. This could be why the procedural concept of personal budgeting developed more slowly ($\Delta M = +0.39$, $d = 0.42$) compared with the declarative concept of types of investments ($\Delta M = +1.89$, $d = 3.04$). Gamified AR is valuable and delivers more than just satisfaction. This reveals how gamified AR provides a personalized, multi-sensory learning environment that addresses many of the criticisms of traditional instruction. The results support the arguments made previously by Abdul Halim et al., (2024).

We showed how MARA 5.0 can offer a customizable, multisensory experience. This study solidifies the view that AR is a formidable pedagogical tool capable of driving genuine engagement, motivation, and deep conceptual understanding, thereby securing long-term educational outcomes.

5. Conclusion and Recommendations

Recommendations

Based on the observed success of the MARA 5.0 system and identified theoretical challenges, the following recommendations are proposed for university leaders and ed-tech developers.

Scaling AR Integration Across Complex Disciplines

The significant increase in comprehension warrants moving AR beyond isolated trials into standard curricula, particularly in disciplines facing the "knowledge-action gap" such as STEM, advanced business management, and financial literacy. Institutionalizing platforms like MARA 5.0 can shift student bodies from passive reception to active problem-solving.

Comprehensive Professional Development for Educators

Addressing faculty unfamiliarity and "AI anxiety" is crucial for AR adoption. Universities should invest in faculty professional development programs that focus on pedagogical alignment, demonstrating how to integrate gamified modules into existing syllabi. Transparent support addressing fears related to technological displacement will reduce resistance and promote effective AR utilization.

Addressing the Student Learning Curve and Accessibility

The modest gains in Academic Confidence suggest a residual technological learning curve. Future AR implementations should include low-stakes, intuitive onboarding tutorials to build student confidence early on. Furthermore, administrators must ensure equitable access to necessary hardware and network infrastructure to prevent widening the digital divide.

Designing for Long-Term Behavioral Change

Ed-tech developers should continue to apply Human-Computer Interaction (HCI) principles to enhance the social interactivity and realism of simulations. For subjects like financial literacy, incorporating elements such as real-time economic stressors and peer-to-peer collaboration could help sustain the observed increases in intrinsic motivation.

Future Research Directions

While this study confirms AR's immediate impact on engagement and comprehension, future research should track longitudinal outcomes to assess knowledge retention over extended periods. Additionally, investigating how different demographic groups interact with AR could provide data for developing more personalized learning environments.

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