

Virtual to Reality: Understanding the Role of Metaverse as a Pedagogical Strategy

Paulina Pui Yun Wong¹, Gary Wai Chung Wong², Piyasuda Pangsapa³ and Daniel Jiandong Shen⁴

¹Science Unit, Lingnan University, Hong Kong SAR

²Department of Economics, Lingnan University, Hong Kong SAR

³School of Global Studies, Thammasat University, Thailand

⁴Soqle Hong Kong Limited, Hong Kong

paulinawong@ln.edu.hk

wongwc@ln.edu.hk

piyasuda@sgs.tu.ac.th

dan@soqle.com

<https://doi.org/10.34190/ejel.21.6.3219>

An open access article under [Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License](#)

Abstract: The use of the metaverse in education has gained increasing attention as a potential supplement to traditional teaching methods. This study aimed to investigate the impact of experiential learning on students' intent to use metaverse learning platforms and to explore how the metaverse can support these approaches. The study included participants from three countries and used metaverse scenes, such as a restaurant or Hong Kong scene, to complete learning tasks and interact with Non-Player Characters (NPCs) to complete assessments over a semester. The results of a correlational analysis showed that pedagogical factors had a greater impact on students' intent to use the metaverse for educational purposes than technical factors, which was unexpected. However, the study also identified challenges in adapting content to match the needs and skills of students who may not be familiar with games, as well as using the metaverse for more advanced pedagogical approaches, due to limitations in integrating content. Based on the findings, recommendations for educators, designers, and researchers are provided to enhance the effectiveness of metaverse-based education. Overall, the results of this study suggest that the metaverse can be a valuable addition to traditional teaching methods.

Keywords: Metaverse, Pedagogical strategies, Experiential learning, Virtual reality education, Immersive learning environments, Game-based learning

1. Introduction

Experiential learning is originally defined by Kolb (1984) as a process in which knowledge is created through the transformation of experience. This approach can be supported by authentic learning, where classroom knowledge is applied in real-world scenarios such as learning about waste in a restaurant or pollution in a city street (Wong, G. W. C., Wong, P. P. Y., and Chong (2022). Authenticity includes incorporating feedback, realism, and diverse student preferences (Farrell, 2020) and may be conducted in the metaverse, a form of virtual environment, frequently implemented with virtual reality (VR) technology. The term “metaverse” refers to a virtual space where users interact with digital objects, characters, and other users (Dwivedi et al., 2022). The metaverse facilitates engaging learning through interactions with characters and objects (Calvert and Abadia, 2020; Kye, et al., 2021). Such interactions may increase students' intent to use the technology, making the process more memorable (Sartaş and Topraklıolu, 2022).

The metaverse is described by Kye et al. (2021) as a smart virtual environment with location-based effects, information recording, a reflection of the real world. Hwang and Chien (2022) elaborate how information might be recorded and transferred more efficiently by employing intelligent virtual agents. Users access the metaverse via desktop computers, mobile devices, and specialized hardware, in addition to virtual reality. While the metaverse is an idea, platforms are developed so that anyone can join and participate. Decentraland, Fortnite, and Minecraft, as mentioned by Owusu-Antwi and Amenuvor (2023), provide immersive digital environments or virtual worlds where users can join, create avatars, interact with others, and engage in various gaming activities. Studies have investigated potential engagements, social exchanges, and applications of the metaverse (Dwivedi et al., 2022). While metaverse platforms are frequently designed for social interactions, they can be used for purposes like education.

Metaverses in education have been noted for topics such as excavations, athletics, safety, and language learning (Yang, Ren and Gu. (2022); Sartaş & Topraklıolu, 2022). Sartaş & Topraklıolu (2022) claim that while metaverse

apps might boost motivation and involvement, more active tasks and storytelling are needed. Cost and effort to set up the virtual environments are also constraints. There's also the issue of cognitive overload, where processing multimedia in educational contexts can place greater demands on working memory than its available capacity (Mayer, 2014). In the metaverse, this challenge is particularly pronounced for beginners, who may experience cognitive overload due to the overwhelming array of controls and options, as noted by Makransky et al. (2019). While VR and metaverses hold promise for enhancing learning experiences, more research is needed to fully understand their potential, particularly their impact on experiential learning. For instance, realistic VR may be costly and difficult to scale to classes that require more sophisticated simulations and scenarios, which can hinder the ability to engage in concrete experiences or reflections as required by experiential learning (Makransky et al., 2019). On the other hand, metaverse concepts such as scene integrations, virtual agents, and authoring tools may allow for content customization (Nah et al., 2022). Thus, the purpose of this study is to investigate how the metaverse could be effectively utilized in an educational setting, considering the different ways it could be applied in various fields of study, receiving student input, and examining the difficulties and constraints associated with deploying metaverses in educational contexts.

In our context, the educational metaverse is a virtual learning environment for students to do educational tasks, talk to each other, take tests, and virtual characters or objects. It can be used in a synchronous in-class setting, or in an asynchronous out-of-class setting, where students access learning materials on their own. The educational metaverse may be supported by pedagogies like the flipped classroom and problem-based learning pedagogy to improve students.

2. Theoretical Background

Virtual reality is a mix of hardware and software to produce an immersive sense of being in a different world (Biocca and Delaney, 1995). Presence, as defined by de Regt, Plangger, and Barnes (2021), is the sensation of being physically present in a virtual environment, a measure of how the user feels present within the VR setting. This encapsulates the authenticity and the subjective reality experienced by the user, distinguishing it from mere graphical fidelity or technical immersion. The process of interpreting an experience is known as reflection. If an individual can connect information in a virtual environment to real life, then reflection is successful (Hamby, Brinberg, and Daniloski, 2017).

Virtual worlds can employ narratives or stories to induce presence and reflection (van Laer, Feiereisen and Visconti (2019). This method, known as narrative transportation, is used in education for virtual field trips and serious games (Markowitz et al., 2018). Wong, G. W. C., Wong, P. P. Y., and Chong (2022) discovered that adopting a virtual platform to permit students to roleplay as real estate brokers boosted student involvement in a real estate transaction simulation.

Dwivedi et al. (2022) categorize the metaverse into four distinct yet interrelated dimensions: an environment that spans realistic to unrealistic realms, interfaces ranging from simple 3D to immersive VR, complex interactions beyond mere conversation, and social value that redefines the metaverse's societal implications. This multifaceted virtual space is not only a collection of digital enhancements, as Zhang et al. (2022) highlight, but also a convergence of augmented and virtual realities, evolving from early virtual communities to today's sophisticated platforms that offer rich, multisensory experiences and user-generated content within an expansive digital economy.

Shin (2022) further suggests that by weaving presence, reflection, and emotion into its fabric, the metaverse can foster a deeply engaging virtual experience that is both immersive and emotionally resonant. Leveraging state-of-the-art graphics techniques, metaverse developers construct environments that merge lifelike 3D settings with interactive elements such as NPCs and avatars. This blend of real and virtual components provides a deeply immersive and engaging user experience in the metaverse (Zhao et al., 2022).

2.1 Previous Studies: Experiential Learning and Metaverse

Previous studies affirm that learners can actively engage in experiential learning by simulating real-life situations within the metaverse's scenes, allowing them to practice skills and apply knowledge in a safe and controlled environment. This can promote practical skills development, for example through virtual field trips, which transport learners to different locations without physically being there (Farrell, 2020; Markowitz et al., 2018). Game-based learning can also be further incorporated with steps like role-play, rules, and resources into educational activities to create an immersive and engaging experience (Mochizuki et al., 2021), to maximize the effects of virtual reality presence and reflection.

The metaverse's capability to facilitate experiential learning is deeply linked with the concepts of presence and reflection. Presence in virtual environments, as defined by de Regt, Plangger, and Barnes (2021), allows for authentic engagement with simulations akin to real-life scenarios. Meanwhile, reflection, the process of interpreting an experience to connect virtual environments to real-life applications (Hamby, Brinberg and Daniloski, 2017), is integral to this learning process. By designing the metaverse with task-based systems employing realistic scenes and specific metaverse tools, educators can create content that fosters both presence and reflection. This design strategy enhances experiential learning by improving conceptualization and engagement, aligning with previous studies that have found efficacy in virtual field trips and game-based learning in achieving practical skills development (Farrell, 2020; Mochizuki et al., 2021).

Besides the adoption of pedagogy, a mechanism to blend an e-learning framework into the metaverse is also required. One framework that can be utilized is the blended-learning RASE framework by Churchill, King, and Fox (2016). The RASE framework consists of four key components: Resources (knowledge or content to fulfil the learning), Activity (tasks required to complete), Support (where students can get help), and Evaluation (how to assess if students are successful) - that can be adapted to the specific needs and requirements of the metaverse environment. The RASE framework can be complemented by an instructional design framework, such as ADDIE (Analysis, Design, Development, Implementation, and Evaluation) to give structured approach to creating instructional materials and programs (Branch, 2009).

Overall, it is crucial to evaluate students' intent to use the metaverse for educational purposes based on various factors, such as enjoyment, ease of use, perceived utility, and prior understanding or perception of the metaverse (Fussell and Truong, 2022). In this context, "intent to use" can be defined as a user's willingness to continue using a technology or system for a specific purpose, such as learning (Davis, 1989). It is well established that factors like perceived usefulness, ease of use, social influences, facilitating conditions are important factors to predict intent to use (Davis, 1989;).

2.2 Research Question Development

While educational metaverses have the potential to create enjoyable learning experiences (Kye, et al., 2021), it is important to consider how they fit into overall learning objectives and how they can be used to support relevant educational materials and assessments (Krotoski, 2010). However, the effectiveness of metaverses for learning is still uncertain due to the lack of research on the topic. For example, Kye et al. (2021) describes the use of simulation technology to link abstract visuals to concrete objects in context of the real world. These simulations can be enhanced using intelligent non player characters to aid decision-making (Hwang and Chien, 2022). However, evidence of learning adoption with metaverse concepts, such as adaptable scenes (Nah et al., 2022) is lesser known. Further, according to, the implementation of methodological and pedagogical models within the metaverse is lesser known, particularly in a learner centred environment (Zhang et al., 2022). A multi-disciplinary approach is needed to develop effective strategies for incorporating metaverse technology into the curriculum.

From these considerations, the research questions are:

RQ1: How can metaverse technology be adapted and integrated into experiential learning to support student learning in the curriculum?

The factors defined by Fussell and Truong (2022) about a virtual environment's ability to invoke intent to use, can be largely grouped into two, where aspects like ease of use and enjoyment can be combined into technological factors while others like usefulness and interesting placed under pedagogy. These two groups (technological and pedagogical) can then be used to influence learning satisfaction, leading to students wanting to continue to use it for their learning experiences, described as "intent to use".

RQ2: To what extent do technological and pedagogical factors affect students' intent to use the metaverse for educational purposes?

2.3 Hypothesis Development

The underlying framework of educational metaverse technology is game-based learning, which can be further supported by experiential learning. The effectiveness of this approach in promoting student learning outcomes depends on factors such as usability, utility, and prior understanding or perception of the metaverse (Fussell and Truong, 2022).

H1: The metaverse technology can support experiential learning pedagogy, through elements of concrete experimentation and reflection to support numerous learning pathways.

In virtual reality education technology adoption, specifically on the metaverse, the success of new technology can depend on a variety of factors, such as perceived utility and usability (Fussell and Truong, 2022). However, pedagogical strategies that are most effective when integrating technology into metaverse platforms are not yet well defined. Without a clear understanding of these strategies, it may be challenging to incorporate metaverse technology into educational curricula. Despite this uncertainty, prior research has consistently shown that both technological and pedagogical factors can impact students' intent to use virtual reality for educational purposes (Fussell and Truong, 2022). As such, it is important to assess how these factors influence students' adoption of the metaverse platform, to evaluate the effectiveness of pedagogical strategies and their ability to support student learning.

H2: Pedagogical factors, such as the perceived usefulness and effectiveness of experiential learning in metaverse technology, will positively influence student learning in using the platform for educational purposes.

H3: Technological factors, such as perceived ease of use, enjoyment, performance expectancy, and attitude toward use, will positively predict students' intent to use the metaverse for educational purposes.

Overall, it is expected that both technical and pedagogical factors affect a student's intent to use the metaverse. Based on the above, Figure 1 outlines our research model.

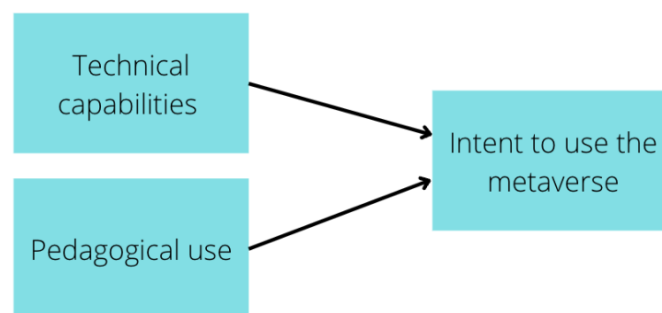


Figure 1: Research model

3. Research Method

This study employed a mixed approach by combining quantitative and qualitative methods to comprehensively understand participants' experiences with the metaverse, evaluate the effectiveness of its design, and identify areas for improvement. The main decisions for choosing a mixed method were:

- **Research Question Scope:** This study investigates how metaverse technology supports experiential learning and the factors affecting students' intent to use it. A mixed methods approach enables quantitative evaluation of student usage and qualitative insights into their engagement.
- **Student Engagement and Usage Intent:** To understand student engagement with metaverse technology and their intent to use it, the study combines quantitative data (from surveys) with qualitative feedback (from interviews and observations), ensuring a thorough exploration of these areas.
- **Diverse Hypotheses Testing:** The hypotheses cover both quantifiable elements (such as ease of use) and subjective aspects (like perceived effectiveness). Mixed methods are used to test these variables, providing a well-rounded analysis.

By combining quantitative survey data and qualitative insights from quest-based learning sessions, the study aimed to provide a comprehensive evaluation of the metaverse's integration into experiential learning within the curriculum.

3.1 Participants

The participants in this study were students from higher education institutions in Hong Kong and Thailand. To ensure effective integration of metaverse technology into pedagogy, classes were selected based on instructors' prior experience in incorporating the use of social learning technology in their classrooms, such as social media for facilitating discussions. These instructors were expected to have a certain level of familiarity with the use of new educational technology, which allowed for more effective control and management of the pedagogy. The samples of the respondents are shown in Table 1. It should be noted that the number of participants was based on the size of the classes.

Table 1: Participants of the study

Group No.	Type	Level	Scene	Participants	Topic	Country	Mode
1	Sustainability	Undergrad	Hong Kong, Restaurant	35, 17-19 years, mixed	Waste and traffic pollution	Hong Kong	Async
2	Sustainability	Masters	Hong Kong, Restaurant	20, 22-25 years, mixed	Waste and traffic pollution	Hong Kong	Sync
3	Sustainability	Undergrad	Sci-fi City	27, 17-19 years, mixed	Sustainable development goals	Thailand	Async
4	Finance	Undergrad	United States	34, 17-19 years, mixed	Great depression (Economic History)	Hong Kong	Sync

3.2 Metaverse Experiences

In the context of this study, two groups in Hong Kong (No 1 and 2 in Table 1) engaged in immersive learning sessions that took place in a restaurant and a virtual Hong Kong city. These sessions were designed to explore the topic of waste management and pollution, specifically focusing on the dilemmas faced by different stakeholders and the information surrounding environmental damage.

In the sustainability class conducted in Thailand (No 3 in Table 1), the focus was on sustainable development goals (SDGs). Due to limitations in lesson time and technological availability, the students were not directly placed in multiple locations. Instead, a generic "sci-fi-like" environment with windmills and greenhouse buildings was utilized to represent a green city. This allowed students to explore various aspects of the SDGs, such as migration, poverty, gender, and the environment.

For the economics class (No 4 in Table 1), the metaverse was used to simulate time travel and delve into the topic of the Great Depression. Non-player characters (NPCs) were designed to portray different perspectives and experiences, including the impacts on farmers, business owners, and regular citizens. This enabled students to engage with the historical context and gain a deeper understanding of the economic theories associated with the Great Depression.

The groups selected from sustainability and economic history classes were particularly well-suited for this study due to the abstract nature of their disciplines. These fields often benefit from visual and experiential learning methods to fully grasp complex concepts and large-scale implications (Luna-Nemecio, Tobón, and Juárez-Hernández, 2020). The metaverse's immersive environment provided a visual context that could make abstract ideas more concrete and understandable.

3.3 Assessment and Measures

3.3.1 Pedagogical approach

In this study, we implemented an authentic learning framework by Farrell (2020), focusing on diverse experiences and personalized challenges for students. We incorporated Churchill, King, and Fox (2016) Resource, Activities, Support, and Evaluation (RASE) framework to strategize these components for the metaverse, an e-learning platform (see Table 2). A central aspect of the learning experience was 'performance', encouraging

active participation in the scene and task completion (Sarita and Topraklıkoğlu, 2022). The metaverse's features were maximized, including authoring tools, to infuse a wide range of content and Non-Player Characters (NPCs), enabling learners to define their learning path and challenge level. NPCs played varied roles from content delivery to fostering social influence, stimulating reflection, and feedback (Oh et al., 2023).

Table 2: E-learning model based on authentic learning (Churchill, King, and Fox (2016); Farrell, 2020)

Category	Resource, Activities, Support, Evaluation (RASE)
Performance	Utilizing metaverse components like NPCs for task completion and learning engagement.
Varying Experiences	Exploring diverse metaverse settings for adaptive and experiential learning.
Challenges	Tackling metaverse tasks autonomously with supportive guidance for skill application.
Feedback	Receiving real-time response from metaverse interactions to inform learning adjustments.
Reflection	Assessing decisions and feedback within the metaverse to deepen self-understanding.
Collaboration	Engaging with virtual agents to enhance teamwork and communicative abilities in the metaverse.

In this study, designing learning experiences such as setting rules and roles within the metaverse became essential, particularly as students would engage through avatars in a third-person perspective. To facilitate this, we employed the game-based learning model by Mochizuki et al. (2020) for its emphasis on interactive, game-based learning and its focus on social learning.

- **Roles:** Learners take on defined roles within the metaverse and complete related tasks, actively engaging with the content and enhancing their learning through direct participation.
- **Rules:** Learners engage with the metaverse through rule-guided quests and tasks that focus and enhance engagement.
- **Gameplay:** An interactive and exploratory design prompts learners to navigate scenes, interact with NPCs, and accrue points via quizzes.
- **Interconnectedness:** The metaverse illustrates the interplay between different scene elements, fostering a comprehensive grasp of the topics.
- **Problem Situation:** Scenarios within the metaverse depict real-world challenges, enabling learners to tackle complex issues in a virtual setting.
- **Resources:** NPCs are strategically placed to act as knowledge hubs, offering various types of information to enhance the learner's understanding, with each selection prompting a distinct response and contributing to a richer educational experience.
- **Social learning:** The metaverse facilitates social learning by enabling learners to engage with NPCs for problem-solving and idea exchange. While direct collaboration isn't featured, the presence of peer avatars in this multiplayer environment promotes observational learning and increased activity.

The learner experience (summarized on Figure 2) would consist of:

Onboarding (10 minutes):

- Learners are briefed on the metaverse learning approach and the Classlet platform via direct instruction and an informative video.
- They install the Classlet application and use a specific code to access the designated metaverse learning environment.

Quest-based Learning (30 minutes):

- Inside the metaverse, learners meet a quest giver who provides them with interactive tasks to be completed by engaging with various NPCs.

- Each NPC interaction challenges the learners to solve problems or answer questions, with immediate feedback provided to facilitate learning progression.

Reflection and Discussion (Post-session):

- Following the interactive session, learners engage in a reflective discussion, often led by an instructor, to articulate their learning experiences.
- This reflective phase is designed to help learners assimilate the knowledge gained and understand the application of their experiences.

This learning experience resembles a cyclic learning experience within the context of experiential learning and is expected to enhance decision-making skills and foster continuous improvement (Figure 2). By incorporating non-player characters (NPCs) to provide feedback, learners can engage in an iterative process of experimentation and reflection. Through concrete experiences, learners make decisions and receive guidance from NPCs, enabling them to analyze the outcomes and refine their decision-making abilities. This approach facilitates active engagement, hands-on learning, and the application of new knowledge to future situations, aligning with the principles of experiential learning (Kolb, 1984).

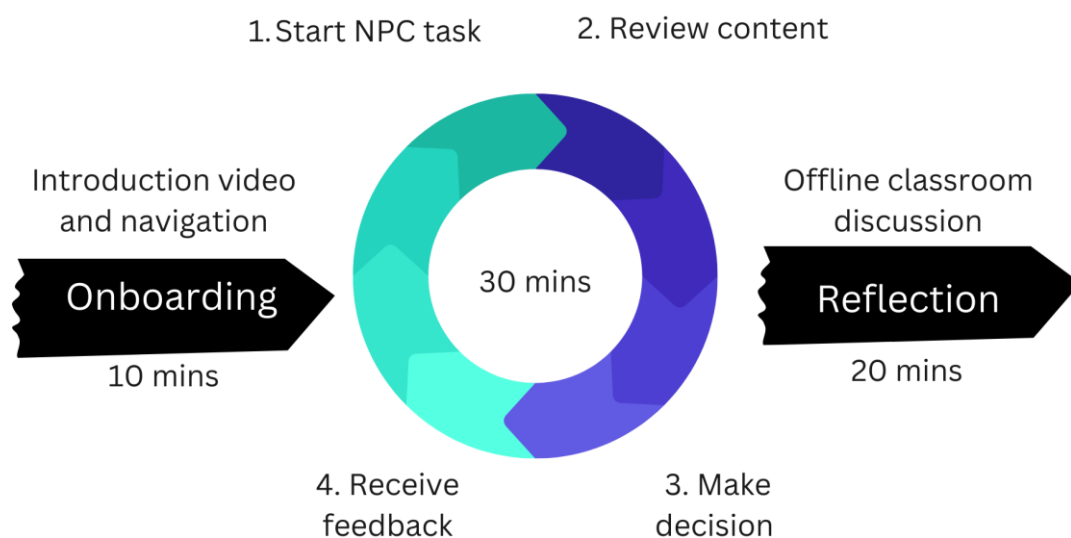


Figure 2: Onboarding process for the metaverse platform

3.3.2 Scene setup (technological)

To set up the scene used for this study, we leveraged a simplified, quiz-like approach for delivering knowledge rather than a comprehensive narrative framework. This was primarily achieved through the design of non-player characters (NPCs), which were created with a specific set of informational requirements. Content was delivered through a user interface that drives description and question as shown in Figure 3. These include:

- **Description:** Each NPC comes with a unique description that provides context and background, helping to situate learners within the metaverse and enhance their understanding of the NPC's role.
- **Question:** Each NPC presents a question related to the learning material, which challenges the learner's understanding and promotes active engagement with the content.

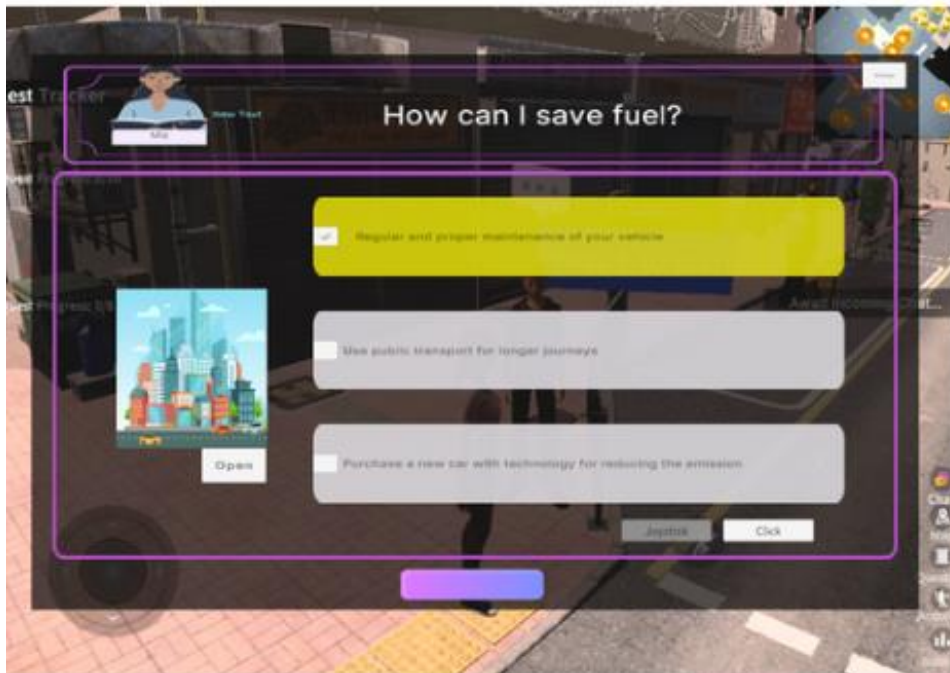


Figure 3: The user interface for a multiple-choice question

- **Options:** For every question, there are three possible answers, out of which only one is correct. This design encourages critical thinking and decision-making skills.
- **Clues:** For each answer option, there is a corresponding clue provided (see Figure 4). This assists learners in deciphering the correct answer and facilitates deeper understanding of the content.

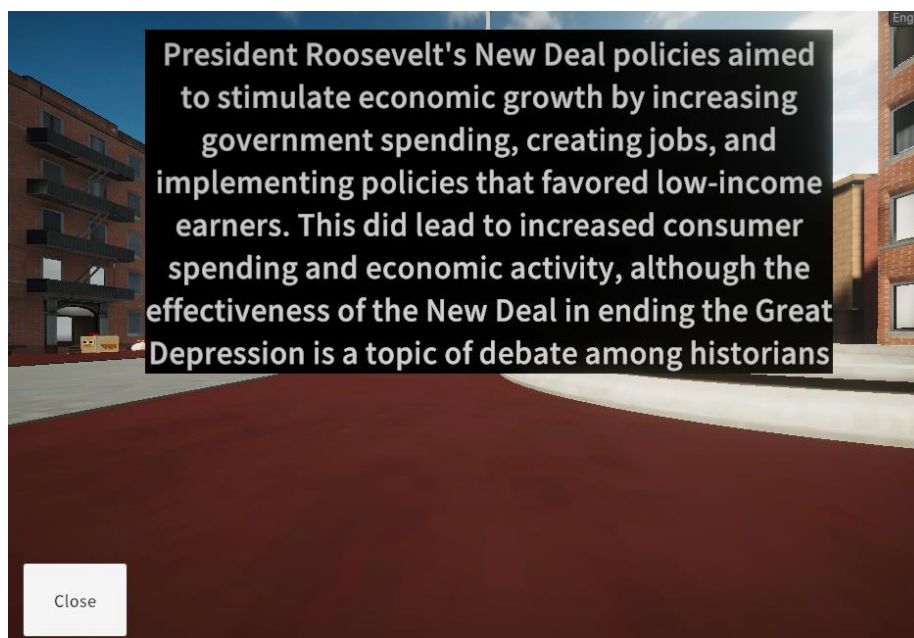


Figure 4: Clues for a multiple-choice question

- **Responses:** Based on the learner's chosen option, the NPC provides a specific response. These responses are designed to give immediate feedback, reinforcing correct understanding and addressing misconceptions.

- **Point System:** A point system is implemented where learners earn one point for a correct answer and zero for a wrong answer. This gamified approach fosters a sense of achievement and motivates learners to fully engage with the learning process.

For this study, we sourced educational content from a range of public data sources like websites and forums. After carefully curating and structuring the material, we formatted it according to the requirements of the metaverse platform. The content was then uploaded to the chosen metaverse platform, making it accessible for learners in the digital learning environment.

The metaverse platform utilized in this study was Classlet (<https://soqgle.com>). Classlet is an application designed for the metaverse, offering users an interactive and immersive learning experience. It employs game- and scenario-based virtual scenes to engage learners in various educational activities. The platform provides authoring tools that enable the creation of realistic and diverse environments, allowing users to complete learning tasks and make decisions within these virtual settings. Through these activities, learners can earn points and achieve objectives, fostering an engaging and interactive learning experience. The platform allows users to browse a semi-open world (constrained within an area), where they could browse a map, track their quests and interest with non-player characters in the scene (Figure 5).



Figure 5: Generic view of the metaverse platform for great depression

For demonstration in this study, we have set up a demo scene, which can be accessed at <https://soqgle.com/demo/demofp.html>. Upon visiting the site, it will automatically direct to the Great Depression scene. To initiate the quest, simply tap on the quest giver (Sheep), and the NPCs required for completing tasks will become available in the scene. It is important to note that the Classlet platform is continuously being improved. Therefore, when accessing the demo, it is expected to be more user-friendly compared to the experiment, as several bugs would have been fixed by then.

3.3.3 The Survey. Predicting student intent to use the metaverse.

To assess the learning outcomes of students in relation to the metaverse, surveys were administered at the end of each session, using a Likert scale ranging from 1 to 5. The surveys aimed to explore students' experiences with the metaverse and their intentions to continue using it for their learning. The study aimed to uncover the relationship between independent variables and the dependent variable, as well as any patterns or trends in the data that could shed light on factors influencing users' intent to continue using virtual reality for learning. Previous research by Fussell and Truong (2022) informed the survey design, providing an enhanced perspective

of the Technology Acceptance Model tailored to the unique pedagogical and technological factors of Virtual Reality in education. This extended TAM model captures critical elements such as the immersive nature of VR and its interactive capabilities, which are pivotal in understanding students' intentions to adopt such dynamic learning tools.

The survey consisted of eight questions, divided into two categories (technological and pedagogical factors) representing the independent variables. Four questions focused on the technical aspects of the Metaverse system, assessing the aesthetic quality, technical functioning, ease of use, and accessibility/usability of the resource. Examples included evaluating visual appeal, performance, and user proficiency in navigating the system. The remaining four questions pertained to the pedagogical implications of the metaverse, gathering feedback on enjoyment, perceived impact on learning and performance, usefulness, and engagement. Additionally, participants were asked about their willingness to use the metaverse system in the future if given the opportunity, which we will also refer to as their intent to use the metaverse. The questions were adapted from previous research by Davis (1989) and Farrell (2020), examining the effectiveness of metaverse technology in supporting student learning. The averaged technology and pedagogy variables were used as independent variables, while the intention to use the metaverse was designated as the dependent variable in the analysis.

To analyze the collected survey data and explore the association between technological and pedagogical factors and students' intention to use the metaverse for education, several statistical procedures were employed. Cronbach's alpha was used to assess the reliability of the technology and pedagogy attributes. Pearson's correlation analysis examined the relationships between the independent variables and the dependent variable, while Shapiro's test and Spearman's rank correlation coefficient assessed the normality and validity of the data. A linear regression analysis was then conducted to determine significant predictors of the intention to use the metaverse, using JASP software (<https://jasp-stats.org/>).

In this study, ethical considerations included informed consent through a clear statement on the survey, ensuring participant understanding and voluntariness. Additionally, students were briefed in class using PowerPoint slides, where the goals and nature of the immersive learning activity were explained in detail. We ensured data confidentiality and participant anonymity, and designed metaverse content to be educational and non-threatening, such as interactive scenarios on waste management and agriculture with semi-cartoon style, non-intimidating 3D models. This approach aimed to provide a safe, engaging learning environment without distressing content.

4. Results

4.1 Use of Metaverse

Instructors utilized the metaverse platform as previously described, which allowed for the integration of real-world applications and game-based learning scenarios. This approach facilitated a diverse range of learning experiences across disciplines. In total, our content packs contained 13,627 words, encompassing descriptions, questions, options, and responses. The words were distributed as follows: Group 1 and 2 used 5,570 words; Group 3 used 3,620 words; Group 4 used 4,437 words. The average word count per participant was 159 for Group 1, 181 for Group 2, and 164 for Group 3. Differences between groups did not surpass the 20% threshold, indicating no significant variance in word count across the groups.

We conducted an online survey at the end of the sessions and received 162 responses. Students were asked to provide three things they liked and three things they felt were opportunities for the metaverse learning experience (Table 3). These responses were collected via an open input text field, which gave students the freedom to express their views on what they liked and what they considered as opportunities within the metaverse learning experience. Typically, 'opportunities' are understood to be areas with potential for enhancement, growth, or development. Selected illustrative quotes from the likes and opportunities are shown on Table 3.

Table 3: Illustrative quotes from post-session surveys

Type	Likes	Opportunities
Aesthetics (Technology)	<p>The design of the environment in the game is so nice that it is trying to show us the street of US at that time, and we can have a better understanding of it</p> <p>These cartoon characters are cute. It will increase my motivation to learn.</p>	<p>The appearance is still lacking in comparison to other game as I play Genshin impact which has similar feature but breath-taking scenery.</p>
Functional (Technology)	<p>First-person game can help immersing into the scenario.</p>	<p>Too many bugs (cannot not close the answering page), confused about the use of the system and too many humans in the system.</p> <p>it is little bit confused when i was controlling the character as there are not clear instructions about what can we do for the next step</p>
Ease of use (Technology)	<p>Easy to control, Npc is easy to find and kind of fun way to learn</p>	<p>I do not know what my progress is (i.e. how much I have already answered). New to us, too advance, need consultant to guide</p> <p>The interface itself is not very smooth and may just cause more stress for people trying to access the information on it.</p>
Fun (Technology)	<p>Games always make class more fun and enjoyable.</p> <p>Its idea is innovative, it covered some additional acknowledgements, the interaction is fun.</p>	<p>Not interesting/beneficial to study since phone's monitor is smaller, also not interesting by reaching the NPC and receive information (although not boring than sit in classroom)</p>
Usable /Access (Pedagogy)	<p>Students are free to try out anything in the game which is very free.</p> <p>Players can try to answer any questions without barriers.</p>	<p>It is little bit confused when i was controlling the character as there are not clear instructions about what can we do for the next step</p>
Improves learning (Pedagogy)	<p>Encourage students to learn more other than lecture notes like the background information provided in every question</p> <p>We get to know more about real global environmental issues which we sometimes ignore or do not clearly notice unless we suffer high temperatures and nature disasters as well as man-made disasters.</p>	<p>The interaction between npc and the player could be more active.</p> <p>More "wrong answer options" should be set in the multiple-choice options.</p>
Useful (Pedagogy)	<p>I appreciate the activities that have to be done in groups because they can help each other plan the event.</p> <p>Not lecture based, self-discovery, and new perspective of learning. Can increase the memory of knowledge through playing the game</p>	<p>I'd rather get to the point when learning subjects, a video would be fine as well, however I see zero value in using a metaverse</p>
Interesting (Pedagogy)	<p>The approach is different from traditional methods of education which might work better for some people.</p> <p>It is more interesting than learning from words, I can learn more information than class and I will feel no stress when learning</p>	<p>not interesting/beneficial to study since phone's monitor is smaller, also not interesting by reaching the NPC and receive information (although not boring than sit in classroom)</p>

4.2 Inferential Statistics

The sample size of 162 (the survey results) was considered appropriate for the analysis conducted in this study. The reliability of the scores was tested using Cronbach's alpha (α) and resulted in a value of 0.930, indicating that the dataset is suitable for correlational analysis. A Pearson's correlation (Appendix B) was calculated to examine the relationship between a student's intent to use the metaverse and various technology and pedagogy attributes. The results showed that the most significant predictor of intent to use the metaverse was how interesting the technology was ($r = 0.798$, $p < .001$), followed by how it improves student learning ($r = 0.702$, $p < .001$). Aesthetics and the functions of the metaverse had the lowest correlations ($r = 0.375$, $p < .001$ and $r = 0.547$, $p < .001$).

Additionally, T-T plots were used to assess the normality of the data, which appeared to be normalized. However, Shapiro's test revealed that the data for technology ($p=0.002$) and pedagogy ($p<0.001$) were not normally distributed. Despite this, the Pearson's correlation coefficients were still significant, indicating a strong relationship between the variables.

To further strengthen the analysis and to provide a robust result, we also calculated the Spearman's rank correlation coefficient. The results (Appendix A) showed that the correlation between intent to use the metaverse and technology attributes ($\rho = 0.601$, $p<.001$) and intent to use the metaverse and pedagogy attributes ($\rho = 0.763$, $p<.001$) were both statistically significant. Similarly, the correlation between technology and pedagogy attributes was statistically significant ($\rho = 0.732$, $p<.001$). These results indicate that there is a moderate to strong correlation between the independent variables (technology and pedagogy attributes) and the dependent variable (intent to use the metaverse) regardless of the correlation measure used.

A linear regression analysis was then conducted with pedagogy as the independent variable and intent to use the metaverse as the dependent variable. The analysis was run using JASP software and a significance level of 0.05 was used. The assumptions of linear regression were checked and met, including linearity, homoscedasticity, and independence of errors. The results showed that pedagogy significantly predicted intent to use the metaverse ($\beta = 0.934$, $p < .001$) with an R-squared value of 0.623, indicating that 62.3% of the variance in intent to use the metaverse can be explained by pedagogy. Additionally, the Root Mean Squared Error (RMSE) value of 0.706 indicates that the model has a good fit with the data. It is relatively low compared to the standard deviation of the dependent variable (intent to use the metaverse) of 1.135, indicating that the model can predict the intent to use metaverse with good accuracy. The overall regression model was statistically significant ($F(2,162) = 65.166$, $p < .001$). Based on these results, it can be concluded that pedagogy is a strong predictor of intent to use the metaverse, with each unit of pedagogy rating contributing to 0.934 for intent to use.

5. Discussion

5.1 The use of Metaverse Learning Strategies (RQ1)

In the context of VR, participants in this study engaged in experiential learning through the stages of Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation, with a focus on VR-specific concepts.

- Concrete Experience: Participants immersed in virtual environments, engaging in hands-on experiences. Metaverse technology enabled real-time feedback, enhancing engagement and presence.
- Reflective Observation: Participants reflected on metaverse-based activities, evaluating actions and connecting virtual experiences to real-life applications.
- Abstract Conceptualization: Participants developed conceptual insights within VR, relating experiences to theoretical principles and considering the metaverse's educational impact.
- Active Experimentation: Participants explored alternatives in VR, engaging in hands-on experimentation. Although they applied skills and iteratively refined strategies, the 30-minute quest-based learning limited evidence of repeated trial and error. Further exploration in extended sessions may reveal deeper insights.

Experiential learning was found to be the easiest to implement since it only requires putting students in a situation and letting them explore. Participants also liked it because many of them like immersion and freedom to go through scenes at their own leisure. Overall, we present the metaverse-based experiential learning model below in Figure 6.



Figure 6: Metaverse-based experiential learning model

Active experimentation in the metaverse presents unique challenges in observing and evidencing successful learning outcomes. The level of realism and individualization required might vary drastically depending on the learning objectives. For instance, sending a student back to 1930 to study the Great Depression raises questions about the required authenticity of that period. Increasing individualization, such as offering access to diverse settings like a farm, a business, or a bank, can enhance learning but might be constrained by the additional effort and cost to develop such intricate environments.

Moreover, the way information is conveyed within the immersive environment must be carefully considered. Should students learn through videos relevant to the scene, engage with characters in active learning stories, or experience a blend of both? The choice of scene types and levels of immersion can profoundly affect understanding and engagement, which might explain why some participants were unclear about the goals or directions.

No specific differences were observed in the use of the metaverse between Thai and Hong Kong cultures, and statistical analysis did not reveal any significant distinctions. This uniformity in engagement may be attributed to the overarching collectivist values prevalent in both societies, which influence how users interact with virtual objects, environments, and shared goals within these immersive platforms, as suggested by Awanis, Schlegelmilch, and Cui (2017).

No differences were observed in the use of the metaverse across various academic disciplines, degree levels, and delivery modes, reflecting its broad applicability and effectiveness in education. This finding resonates with Shin's (2022) insights on the metaverse's potential to integrate emotions, embodiment, and presence, which likely contributed to the platform's adaptability and consistent engagement levels noted in our study.

Overall, the use of a metaverse platform as a learning strategy proved to be effective in achieving the desired learning goals in both Hong Kong and Thailand. The incorporation of simulations of real-world situations and game-based learning allowed students to engage in immersive experiences that were directly relevant to the subject matter at hand. For example, students had the opportunity to assume the roles of characters traveling back in time to the Great Depression or working in a restaurant to explore concepts related to food waste. These experiences were facilitated using avatars and interactive elements such as clicking on items and interacting with non-player characters (NPCs). To ensure alignment with the learning objectives, specific game-like rules and quests were created, requiring the completion of certain tasks and interactions. When designing lessons within the metaverse, careful consideration was given to assessment methods, information delivery, and the appropriate narrative structure that best supported the intended educational outcomes.

Technological features

The metaverse platform used in this study has demonstrated its potential for supporting a range of pedagogical methods, including problem-based learning and flipped classroom approaches. The platform's authoring tools allow for the creation of user-generated scenes, setting it apart from other VR solutions and providing opportunities for customization and tailored learning experiences. In this context, we would articulate that an educational metaverse can set itself apart from other VR solutions or game-based solutions by providing the ability for users to actively participate in the creation and customization of virtual environments and learning experiences. The use of authoring tools empowers educators and learners to design and develop their own virtual scenarios, incorporating specific learning objectives and content relevant to their educational goals.

In terms of process and operational use to integrate the metaverse platform, the creation of each content pack required two to three weeks of preparation and research. Similarly, designing and deploying each 3D scene took about three weeks. This process included developing the assets, integrating them into the Classlet metaverse engine, and optimizing these assets. Optimization involved tasks such as reducing the polycount of 3D models for smoother performance and tagging the Non-Player Characters (NPCs) to prepare them for content mapping.

Notably, Classlet utilizes a keyword tagging system to link the NPCs within a scene to relevant learning content that is uploaded to the server. This system ensures that each NPC in the metaverse is effectively tied to the educational material, facilitating the learning process within the immersive 3D environment.

Some participants also expressed some concerns and challenges related to the metaverse learning implementation. Some participants found the questing system to be limited and expressed difficulties in monitoring their own progress. They also mentioned that not all students were familiar with using mobile game platforms, highlighting the need for instructors to provide guidance and support. To address confusion and improve the user experience, the inclusion of visual signals, such as waypoints, could help students navigate and stay motivated to fulfil their learning objectives (John et al., 2020).

The comparison of metaverse graphics to popular mainstream AAA games, as mentioned by participants, highlights a known challenge in serious games (Starks, 2014). It is important to consider that the positioning and explanation of the platform at the beginning of the learning experience can influence participants' perceptions. While the metaverse platform may not have the same level of graphical fidelity as AAA games, its primary focus is on educational content and learning outcomes. To assist students in comprehending and harnessing the educational benefits of the metaverse, teachers must provide them with structured and easily comprehensible instructions, accompanied by necessary technical support (Krotoski, 2010).

Furthermore, there is potential for leveraging generative AI technologies like Generative Pre-trained Transformer (GPT) models to further enhance the interaction between players and non-player characters (NPCs). GPT is a deep learning model that has been pre-trained on a large corpus of text data and can generate human-like text based on the given input. This can be helpful to generate dialogue or scenarios so that the experience can depend less on scripted dialogue. However, more research is needed to understand the implications and implementation of such processing models.

The Classlet metaverse platform utilized in our study provided a secure learning environment through a private code-based access system, ensuring that only students with the code, distributed during class, could join the specific scenes. Additional security can be added by implementing email whitelisting, but this would increase administrative effort, presenting a trade-off for institutions to consider.

Acknowledging the limitations of metaverse learning strategies, it becomes evident that replicating real-world experiences in the metaverse poses significant challenges. Realism, particularly in subjects that require physical interaction, remains a hurdle. While immersive virtual reality using head-mounted devices can enhance the experience, as Lan (2020) notes, they may be cost-prohibitive for widespread implementation. Additionally, equitable access to these technologies is a major concern, with performance varying based on the user's device; not everyone has access to high-powered machines and devices. In addition to these technological constraints, there is a considerable effort involved in developing detailed learning scenarios and transforming existing educational content into game-based formats. This process can be time-consuming and resource-intensive, presenting another layer of complexity in the effective implementation of metaverse learning strategies.

Despite these limitations, the metaverse holds considerable potential for educational innovation. It presents opportunities that traditional learning environments may not offer, such as the creation of personalized learning pathways and alternate realities that respond to student actions, allowing learners to see the consequences of

their choices in a controlled environment. Furthermore, the integration of advanced technologies like AI has the potential to enhance these virtual environments, facilitating more dynamic and interactive experiences.

H1 Conclusion: The assertion that metaverse technology can support experiential learning is partially substantiated. The stages of concrete experience, reflective observation, and abstract conceptualization were successfully facilitated by the metaverse, as demonstrated by the students' engagement. Active experimentation, however, was hindered by the virtual environment's limitations in realism and the capacity for iterative, variable scenarios. Future studies will attempt to further this aspect with learning pathways and artificial intelligence integration.

5.2 Intent to use the Metaverse for Learning (RQ2)

Pedagogy-related factors predicted intent to use better than technical components, with a β coefficient of 0.934 and an R-squared value of 0.623. This shows that our metaverse for cross-disciplinary courses and flipped classroom style increased students' interest and enjoyment in learning. The overall regression model was statistically significant ($F(2,162) = 65.166, p < .001$), supporting the hypothesis that pedagogy influences students' metaverse use. Our findings also suggest that metaverse pedagogy-based strategies like the flipped classroom can improve learning outcomes and student engagement.

It was interesting that the regression analysis showed that pedagogy-related factors (e.g., perceived utility) had a greater impact on students' willingness to use the metaverse for instructional purposes than technical factors (e.g. ease of use). This was surprising because many metaverse or virtual reality education research focuses on technological factors like presence activation (van Laer, Feiereisen and Visconti (2019); de Regt, Plangger, and Barnes (2021). Pedagogical aspects may be more important than technical factors because intrinsic motivation, such as the desire to learn, may be more influential (Lavoué, et al., 2021). Nonetheless, it is also possible that even greater immersion or performance in the metaverse platform, as technology improves, may yield higher results, like a higher effect size beyond 0.646 which was recorded in this study.

This finding suggests that intrinsic motivation, such as the desire to learn, may be more influential than the technical features of the platform. According to Bandura (1986), individuals are more intrinsically motivated when they perceive they are competent and have more control. Participants in the study reported that they could browse in a relaxed way and retrieve more information than they otherwise couldn't in a classroom. Using a goal-based system in the platform, such as requiring to complete a number of multiple-choice questions also allows for increased motivation. This means that educators should aim to create learning environments that foster students' sense of competence and control, that can challenge them appropriately, and provide clear feedback. This is consistent with Farrell's recommendation of authentic learning (2020).

In addition, presence and immersion in virtual reality can also contribute to creating learning purpose and meaning, as well as enhancing students' emotions and embodiment. The metaverse platform offers a depth of experience that traditional classrooms cannot provide, allowing students to explore and experiment with a range of scenarios that are not possible in a physical setting. This depth of experience can also lead to deeper reflection and personal meaning-making, as students are able to connect the classroom knowledge to real-life situations. For example, being in a restaurant to interview owners and kitchen staff about food waste helps to put the learning content into context. Shin (2022) suggests that the metaverse has the potential to connect emotions, embodiment, and presence together, providing a more holistic learning experience. Therefore, incorporating the use of VR and metaverse platforms into education can not only increase motivation, but also enhance the overall learning experience for students.

Despite the use of presence and immersion, some students reported that the process of obtaining information through the platform was inefficient and slow. Incorporating narratives into the metaverse platforms can potentially improve learning efficiency. By incorporating narratives, the learning process can become more targeted and straightforward, as it is guided by a story direction. For example, in the language learning class described above, the use of a story helped to engage students and provide a clear goal for their learning. This is consistent with research that suggests narratives can enhance learning by providing structure, context, and meaning (Schank and Abelson, 1994). Therefore, the use of narratives in VR and metaverse platforms can be a potential solution to address the issue of learning efficiency.

Finally, the benefits of using the metaverse for learning can be linked in part to the employment of metaverse authoring tools. These tools allow instructors to convert existing curricula into dynamic, immersive scenes, that can be shared across varying cultural and geographic classes. The dynamic nature of the scenes also allowed the customization of goals, through the setup of quests and non-player characters, which enhanced scaffolding

(Zimmerman, Bandura and Martinez-Pons (1992). These authoring tools are available through a web portal to assist teachers manage content (Nah et al., 2022). In our study, students re-used scenarios across countries, therefore fostering a global and interconnected mindset.

H2 Conclusion: The study confirmed that pedagogical factors have a strong influence on students' engagement and intention to use the metaverse for learning, as indicated by the robust statistical support from the regression model.

H3 Conclusion: Technological factors, while initially engaging, were less influential than pedagogical elements in determining students' sustained intent to use the metaverse, suggesting that effective learning strategies are paramount for long-term engagement.

5.3 Significance: An Adaptive Framework for Metaverse Learning Environments

In this study, a framework for metaverse learning was developed, providing a structure for educators and learners to create immersive educational experiences. This framework allows for the design and development of virtual scenarios that align with educational objectives. It includes various pedagogical methods, such as problem-based learning and flipped classroom approaches, suitable for different educational settings. The framework's use of authoring tools enables the generation of specific content, crucial for tailored learning experiences. Operational processes, including the creation of 3D assets and optimization for the Classlet metaverse engine, are core aspects of this framework. These elements support the implementation of metaverse learning and encourage consistency and efficiency in developing metaverse environments. Its broad applicability and adaptability make it a significant contribution to the academic community, providing a method for integrating immersive technologies in educational contexts.

5.4 Limitations

This study collected data from several classes due to the lack of metaverse research on various subjects. This study's 162 participants were sufficient, however inconsistent teaching methods may have affected the results. To overcome these obstacles and reinforce our findings, future research should use a larger sample of classes organized by similar topics and broader teaching methods. This would demonstrate how the metaverse can teach various subjects and approaches. Additionally, it is important to highlight that the data obtained in this study are self-reported and that no control group was employed.

Despite the aforesaid restrictions, our study's Cronbach Alpha was satisfactory, indicating data reliability. However, additional study is needed to understand how serious games affect learner engagement and to design successful ways for promoting uptake and use of these instructional tools.

6. Conclusion

In conclusion, our study contributes to the metaverse in education literature by affirming the potential of immersive learning to increase student engagement through a cyclical process of experiential learning. The use of the metaverse in education effectively supported the stages of Concrete Experience and Abstract Conceptualization, aligning with the experiential learning theory. However, limitations in realism within the virtual environment slightly curtailed the extent of Active Experimentation.

Addressing our research questions, we found that:

- RQ1: Metaverse learning strategies foster experiential learning, evidenced by the active engagement of students within virtual environments. This engagement supports the hypothesis that metaverse strategies can enhance concrete and abstract learning experiences.
- RQ2: Pedagogical constructs had a more substantial impact on the intent to use the metaverse for learning than technical factors, emphasizing the importance of instructional design. This reinforces the hypothesis that pedagogical considerations are paramount in the adoption and effectiveness of educational technologies like the metaverse.

The study's limitations include the variability of teaching methods across classes, reliance on self-reported data, and the absence of a control group. Although the sample size was sufficient, future research would benefit from a larger, more uniform sample to solidify findings. Despite these issues, data reliability was confirmed to be satisfactory.

By integrating game-based elements and authentic simulation environments, our research contributes to the body of literature by providing empirical evidence supporting varied roles and dynamic rules within the

metaverse. Despite the benefits, we note instances of cognitive overload, indicating the need for careful design considerations to prevent distractions and enhance focus. In response to the study's findings, future research will focus on the relationship between gaming familiarity and academic achievement in metaverse learning.

The subsequent research agenda should explore:

- The relationship between gaming familiarity and academic achievement in metaverse learning, to discern how prior gaming experience influences educational outcomes.
- Strategies to mitigate cognitive overload in metaverse educational settings, aiming to balance interactive and educational elements.
- The role of artificial intelligence in personalizing learning experiences within the metaverse, which could revolutionize the interactivity and adaptability of virtual learning environments.

Overall, our study underscores the necessity of a strong pedagogical foundation in designing educational metaverse applications, advocating for a thoughtful balance between engaging content and educational rigor.

Conflicts of Interest Disclosure

Daniel Shen, a co-author, holds stock in Classlet. Despite this, the authors have rigorously adhered to objective and critical analysis throughout the research process. The findings and conclusions presented are the result of an independent and unbiased evaluation of the data.

Acknowledgement

This study was funded by Lingnan University, Hong Kong (Teaching Development Grant, Project Code: 102716).

References

- Awanis, S., Schlegelmilch, B. B., and Cui, C. C. (2017). Asia's materialists: Reconciling collectivism and materialism. *Journal of International Business Studies*, 48(8), 964–991. <https://doi.org/10.1057/s41267-017-0096-6>
- Bandura, A. (1986). Social foundations of thought and action: A social cognitive theory. Prentice-Hall.
- Bandura, A. (2008). Observational learning. In W. Donsbach (Ed.), *The International Encyclopedia of Communication* (p. wbieco004). John Wiley & Sons, Ltd. <https://doi.org/10.1002/9781405186407.wbieco004>
- Biocca, F., and Delaney, B. (1995). Immersive virtual reality technology. In F. Biocca & M. R. Levy (Eds.), *Communication in the age of virtual reality* (pp. 57–124). Lawrence Erlbaum Associates, Inc. (Reprinted in modified form from "Journal of Communication," Aut 1992)
- Branch, R. M. (2009). *Instructional design: The ADDIE approach*. Springer.
- Calvert, J. and Abadia, R. (2020). Impact of immersing university and high school students in educational linear narratives using virtual reality technology. *Computers & Education*, 159, 104005. <https://doi.org/10.1016/j.compedu.2020.104005>
- Churchill, D., King, D. and Fox, B. (2016). A framework for designing student-centered blended learning environments. In M. Ally & A. Tsinakos (Eds.), *Proceedings of the International Conference on Mobile, Blended and Seamless Learning* (pp. 31-35). Springer.
- Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3), 319. <https://doi.org/10.2307/249008>
- Dwivedi, Y. K., Hughes, L., Baabdullah, A. M., Ribeiro-Navarrete, S., Giannakis, M., Al-Debei, M. M., Dennehy, D., Metri, B., Buhalis, D., Cheung, C. M. K., Conboy, K., Doyle, R., Dubey, R., Dutot, V., Felix, R., Goyal, D. P., Gustafsson, A., Hinsch, C., Jebabli, I., ... Wamba, S. F. (2022). Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International Journal of Information Management*, 66, 102542. <https://doi.org/10.1016/j.ijinfomgt.2022.102542>
- de Regt, A., Plangger, K. and Barnes, S. J. (2021). Virtual reality marketing and customer advocacy: Transforming experiences from story-telling to story-doing. *Journal of Business Research*, 136, 513–522. <https://doi.org/10.1016/j.jbusres.2021.08.004>
- Farrell, C. (2020). Do international marketing simulations provide an authentic assessment of learning? A student perspective. *The International Journal of Management Education*, 18(1), 100362. <https://doi.org/10.1016/j.ijme.2020.100362>
- Fussell, S. G., and Truong, D. (2022). Using virtual reality for dynamic learning: An extended technology acceptance model. *Virtual Reality*, 26(1), 249–267. <https://doi.org/10.1007/s10055-021-00554-x>
- Hamby, A., Brinberg, D., and Daniloski, K. (2017). Reflecting on the journey: Mechanisms in narrative persuasion. *Journal of Consumer Psychology*, 27(1), 11–22. <https://doi.org/10.1016/j.jcps.2016.06.005>
- Hwang, G.-J., and Chien, S.-Y. (2022). Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective. *Computers and Education: Artificial Intelligence*, 3, 100082. <https://doi.org/10.1016/j.caeai.2022.100082>

- John, B., Lang, D. J., von Wehrden, H., John, R., and Wiek, A. (2020). Advancing decision-visualization environments—Empirically informed design recommendations. *Futures*, 123, 102614. <https://doi.org/10.1016/j.futures.2020.102614>
- Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs, N.J: Prentice-Hall.
- Krotoski, A. (2010). Serious fun with computer games. *Nature*, 466(7307), 695–695. <https://doi.org/10.1038/466695a>
- Kye, B., Han, N., Kim, E., Park, Y., and Jo, S. (2021). Educational applications of metaverse: Possibilities and limitations. *Journal of Educational Evaluation for Health Professions*, 18, 32. <https://doi.org/10.3352/jeehp.2021.18.32>
- Luna-Nemecio, J., Tobón, S., and Juárez-Hernández, L. G. (2020). Sustainability-based on socioformation and complex thought or sustainable social development. *Resources, Environment and Sustainability*, 2, 100007. <https://doi.org/10.1016/j.resenv.2020.100007>
- Lavoué, É., Ju, Q., Hallifax, S., and Serna, A. (2021). Analyzing the relationships between learners' motivation and observable engaged behaviors in a gamified learning environment. *International Journal of Human-Computer Studies*, 154, 102670. <https://doi.org/10.1016/j.ijhcs.2021.102670>
- Makransky, G., Terkildsen, T. S. and Mayer, R. E. (2019). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learning and Instruction*, 60, 225–236. <https://doi.org/10.1016/j.learninstruc.2017.12.007>
- Markowitz, D. M., Laha, R., Perone, B. P., Pea, R. D. and Bailenson, J. N. (2018). Immersive Virtual Reality Field Trips Facilitate Learning About Climate Change. *Frontiers in Psychology*, 9, 1–20. <https://doi.org/10.3389/fpsyg.2018.02364>
- Mochizuki, J., Magnuszewski, P., Pajak, M., Krolikowska, K., Jarzabek, L., and Kulakowska, M. (2021). Simulation games as a catalyst for social learning: The case of the water-food-energy nexus game. *Global Environmental Change*, 66, 102204. <https://doi.org/10.1016/j.gloenvcha.2020.102204>
- Nah, F., Shen, D., Wong, P., Wang, R., Techanamurthy, U., Tong, E., Geng, H., Pangsapa, P., and Chew, S. "Enhancing Literacy Education with Narrative Richness in the Metaverse," *Proceedings of the 21st Annual Pre-ICIS Workshop on HCI Research in MIS*, Copenhagen, Denmark, 11 December 2022.
- OECD. (2018). *Global competency for an inclusive world*. Paris: OECD Publishing. <https://www.oecd.org/education/Global-competency-for-an-inclusive-world.pdf>
- Oh, H. J., Kim, J., Chang, J. J. C., Park, N., and Lee, S. (2023). Social benefits of living in the metaverse: The relationships among social presence, supportive interaction, social self-efficacy, and feelings of loneliness. *Computers in Human Behavior*, 139, 107498. <https://doi.org/10.1016/j.chb.2022.107498>
- Owusu-Antwi, K. and Amenuvor, F. E. (2023). Understanding the metaverse: A review of virtual worlds and augmented reality environments. *Current Journal of Applied Science and Technology*, 42(23), 42–48. <https://doi.org/10.9734/cjast/2023/v42i234172>
- Sarıtaş, M. T. and Topraklıkoğlu, K. (2022). Systematic literature review on the use of metaverse in education. *International Journal of Technology in Education (IJTE)*, 5(4), 586–607. <https://doi.org/10.46328/ijte.319>
- Schank, R. C. and Abelson, R. P. (1994). Knowledge and memory: The real story. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 31–74). Hillsdale, NJ: Erlbaum.
- Shin, D. (2022). The actualization of meta affordances: Conceptualizing affordance actualization in the metaverse games. *Computers in Human Behavior*, 133, 107292. <https://doi.org/10.1016/j.chb.2022.107292>
- Starks, K. (2014). Cognitive behavioral game design: A unified model for designing serious games. *Frontiers in Psychology*, 5. <https://www.frontiersin.org/articles/10.3389/fpsyg.2014.00028>
- Stoiber, C., Ceneda, D., Wagner, M., Schetinger, V., Gschwandtner, T., Streit, M., Miksch, S., & Aigner, W. (2022). Perspectives of visualization onboarding and guidance in VA. *Visual Informatics*, 6(1), 68–83. <https://doi.org/10.1016/j.visinf.2022.02.005>
- van Laer, T., Feiereisen, S., and Visconti, L. M. (2019). Storytelling in the digital era: A meta-analysis of relevant moderators of the narrative transportation effect. *Journal of Business Research*, 96, 135–146. <https://doi.org/10.1016/j.jbusres.2018.10.053>
- Wong, G. W. C., Wong, P. P. Y., and Chong, J. C. M. (2022). Low-fidelity buyer seller simulations can encourage authentic learning experiences. *International Review of Economics Education*, 40, 100241. <https://doi.org/10.1016/j.iree.2022.100241>
- Yang, F., Ren, L., and Gu, C. (2022). A study of college students' intention to use metaverse technology for basketball learning based on UTAUT2. *Heliyon*, 8(9), e10562. <https://doi.org/10.1016/j.heliyon.2022.e10562>
- Zhao, Y., Jiang, J., Chen, Y., Liu, R., Yang, Y., Xue, X., and Chen, S. (2022). Metaverse: Perspectives from graphics, interactions and visualization. *Visual Informatics*, 6(1), 56–67. <https://doi.org/10.1016/j.visinf.2022.03.002>
- Zhang, X., Chen, Y., Hu, L. and Wang, Y. (2022). The metaverse in education: Definition, framework, features, potential applications, challenges, and future research topics. *Frontiers in Psychology*, 13, 1016300. <https://doi.org/10.3389/fpsyg.2022.1016300>
- Zimmerman, B. J., Bandura, A. and Martinez-Pons, M. (1992). Self-motivation for academic attainment: The role of self-efficacy beliefs and personal goal setting. *American Educational Research Journal*, 29(3), 663–676. <https://doi.org/10.3102/00028312029003663>

Appendix A

Correlation Table													
					Pearson					Spearman			
				n	r		p		VS-MPR†	rho		p	VS-MPR†
Intent		-	Avg Tech	163	0.626	***	< .001		2.050×10 ⁺¹⁶	0.601	***	< .001	4.162×10 ⁺¹⁴
Intent		-	Avg Pedagogy	163	0.787	***	< .001		3.613×10 ⁺³²	0.763	***	< .001	1.834×10 ⁺²⁹
Avg Tech		-	Avg Pedagogy	163	0.776	***	< .001		1.077×10 ⁺³¹	0.732	***	< .001	4.889×10 ⁺²⁵
* p < .05, ** p < .01, *** p < .001													
† Vovk-Sellke Maximum p -Ratio: Based on the p-value, the maximum possible odds in favor of H ₁ over H ₀ equals 1/(-e p log(p)) for p ≤ .37 (Sellke, Bayarri, & Berger, 2001).													

Appendix B

Linear regression of technology, pedagogy and intent

Model Summary - Intent									
Model		R		R ²		Adjusted R ²		RMSE	
H ₀		0.000		0.000		0.000		1.135	
H ₁		0.789		0.623		0.613		0.706	

ANOVA													
Model				Sum of Squares		df		Mean Square		F		p	
H ₁		Regression		129.862		4		32.466		65.166		< .001	
		Residual		78.715		158		0.498					
		Total		208.577		162							
<i>Note.</i> The intercept model is omitted, as no meaningful information can be shown.													

Coefficients									
Model			Unstandardized	Standard Error	Standardized ^a	t	p		
H ₀		(Intercept)	3.724	0.089		41.901	< .001		
H ₁		(Intercept)	0.266	0.245		1.087	0.279		
		Avg Tech	0.044	0.100	0.035	0.441	0.660		
		Avg Pedagogy	0.934	0.100	0.763	9.385	< .001		
		Offline? (Yes)	-0.111	0.120		-0.925	0.357		
		Group? (Yes)	-0.080	0.124		-0.646	0.519		
^a Standardized coefficients can only be computed for continuous predictors.									

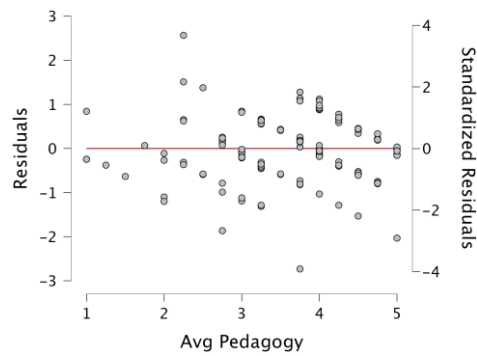
Descriptives								
	N		Mean		SD		SE	
Intent	163		3.724		1.135		0.089	
Avg Tech	163		3.319		0.892		0.070	
Avg Pedagogy	163		3.630		0.927		0.073	

Residuals Statistics							
	Minimum	Maximum	Mean	SD	N		
Predicted Value	1.156	5.157	3.724	0.895	163		
Residual	-2.732	2.566	4.768×10 ⁻¹⁸	0.697	163		
Std. Predicted Value	-2.868	1.600	-2.084×10 ⁻¹⁶	1.000	163		

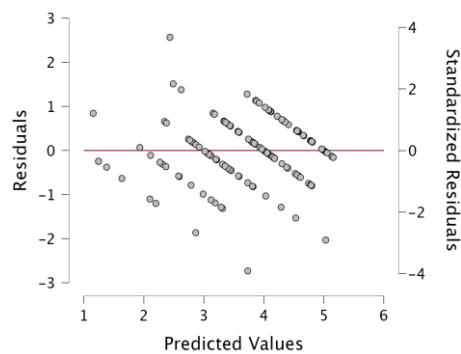
Residuals Statistics							
		Minimum	Maximum	Mean	SD	N	
Std. Residual		-3.936	3.718	4.805×10^{-4}	1.004	163	

Residuals vs. Covariates

Residuals vs. Avg Pedagogy



Residuals vs. Predicted



Q-Q Plot Standardized Residuals

