Liang, J. , Li, G., Zhang, F., Fan, D. & Luo, H. (2023). Benefits and challenges of the educational metaverse: Evidence from quantitative and qualitative data. *Journal of Educational Technology Development and Exchange*, *16*(1), 71-91

Benefits and Challenges of the Educational Metaverse: Evidence from Quantitative and Qualitative Data

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Abstract: *The metaverse, as a more advanced form of virtual reality, has great potential for education because of its unique affordances for enhancing immersion, interaction, and presence. However, because its development is still in its infancy, there are few empirical studies on the application of metaverse in education. There is insufficient empirical evidence from the literature regarding its effectiveness and valued design features, as well as its advantages and disadvantages as a technology-enhanced learning environment. Utilizing the case study method, this study designed and implemented a 40-minute psychology course with 31 undergraduate students in the metaverse using the Virbela platform and collected both quantitative and qualitative data to empirically explore the benefits and challenges of the educational metaverse. The quantitative results showed that the students reported good learning experiences in the metaverse, but their learning outcomes were unsatisfactory, just over the passing level. The qualitative results revealed useful design features and common technical challenges of the educational metaverse. Based on the results, several implications for designing and developing effective courses in the educational metaverse were proposed.*

Keywords: educational meraverse, learning experience, learning outcome, design features, technical challenges

1. Introduction

The term "metaverse," which has gained increasing popularity since 2021, contains two components, meta (the Greek prefix meaning after, post, or beyond) and verse (shorthand for "universe"). The term was coined in Neal Stephenson's (2003) science fiction novel Snow Crash to describe a virtual cyberspace parallel to real life. The definition of the metaverse is still currently evolving, and there is no commonly accepted definition. Some scholars have suggested that it refers to a created world, in which people can "live" under the rules defined by the creator (Hwang & Chien, 2022). Mystakidis (2022) suggested that the metaverse was an interconnected web of social, networked, persistent multiuser immersive environments. From a technological point of view, the metaverse is also a new type of internet application and social form that integrates a variety of new technologies, such as extended reality (XR), digital twin–based technologies, blockchain technologies, 5G, cloud computing, and IoT technologies (Ning et al., 2021). Allowing for these diverse attributes, metaverse is, in short, a virtual space hosted on the Internet, where multiple users can live socially and achieve multimodal interaction using several new technologies. The metaverse is also a changing force that seeks to disrupt the status quo in many industries, including entertainment, business, offices, and healthcare (Xu et al., 2022).

The metaverse is considered to have great potential for education. Kye et al. (2021) stated that it was a new space for social communication where students would have a higher degree of freedom to create and share knowledge. In addition, it could also offer a higher level of immersion through virtualization. The metaverse can promote interaction among students and increase their learning motivation and engagement (Erturk & Reynolds, 2020), and traditional learning styles are believed to change in metaverse, so instructional efficiency and learning experience are likely to be enhanced (Chen, 2022). The metaverse can also provide more immersive scenarios (Tlili et al., 2022) that allow learners to learn or practice in environments that they would not experience in the real world, thus opening up more possibilities for their future (Hwang & Chien, 2022; Zhang et al., 2022). In addition, the metaverse has advantages in saving educational costs; for example, it allows students to conduct physics and chemistry experiments and repair large machinery in a virtual space, avoiding the loss of raw materials (Suzuki et al., 2020; Siyaev & Jo, 2021).

However, the development of the metaverse is still in its infancy (Xu et al., 2022). Although there is growing hype about the metaverse concept, its application in educational practice is still lacking (Lim et al., 2022). Much of the current research on the educational metaverse has been conducted only at the theoretical level, with an insufficient number of empirical studies. In a review of the literature on educational metaverse (Tlili et al., 2022), it was found that only 18.8% of the studies used quantitative methods and 39.6% of the studies used qualitative methods or mixed methods. Notably, the other 41.7% of the studies focused on reviewing the literature and elaborating on theories, without collecting any empirical data. However, the feasibility and effectiveness of the educational metaverse need further verification with more abundant empirical evidence.

To address this research gap, we therefore conducted an empirical case study using the metaverse platform Virbela to extend our understanding regarding the benefits and challenges of using the metaverse for university teaching. The primary purpose of this study was to explore the students' learning outcomes and experiences in the educational metaverse. We also sought to identify the useful design features and common technical challenges of the educational metaverse. The following questions guided our research investigation:

(1) What are the student learning experiences and outcomes in the educational metaverse?

(2) What features of the educational metaverse were valued and not valued by the students and why?

(3) What are the common technical challenges facing the educational metaverse?

2. Literature Review

2.1. History and Key Characteristics of the Metaverse

The development of the metaverse can be summarized into five stages (Dionisio et al., 2013; Lee et al., 2021). The stages include: (1) the literature on virtual worlds, (2) text-based interactive games, (3) virtual open worlds, (4) massively multiplayer online games (MMOGs), and (5) the new era of the metaverse. Each stage has been driven by the emergence of new technologies. With the advent and rapid development of computers, most of the early metaverse interventions appeared in the form of games, where users could log in with their corresponding avatars and use voice and text to communicate. The MMOG phase is also generally recognized as a prototype of the metaverse due to the rapid development of the Internet when MMOGs (such as Roblox and Virbela) became popular (Duan et al., 2021; Lee et al., 2021). Typical of this phase was the game Second Life, in which players could not only interact with other players in a 3D virtual environment but could also use virtual currency to buy and build various items, as though it were their own second life (Inman et al., 2010). Finally, during the new era of metaverse (the early 21st century–present), a range of new technologies (e.g., blockchain, XR) is beginning to be combined within the metaverse in an attempt to achieve a truly decentralized virtual world, such as VR Chat, Alien Worlds, and Decentraland (Duan et al., 2021).

Different views exist in the literature regarding the characteristics of metaverse. Roblox CEO Dave Baszucki suggested that a metaverse had eight features: identity, variety, friends, anywhere, immersive, economy, low friction, and civility (Lin, 2021). Contreras et al. (2022) identified three key characteristics of a metaverse: (1) the metaverse, like life, must be functioning at all times; (2) the user must be able to communicate and interact with peers in the metaverse; and (3) the metaverse must be subject to the laws of physics to make it more real and as though experienced in the first person. To distinguish the metaverse from mixed reality (MR), the following three unique metaverse characteristics have been proposed: the metaverse is shared, persistent, and decentralized (Hwang & Chien, 2022). These characteristics define and limit the metaverse in terms of virtual identity and property, immersion and simulation, social interaction and community, and also present unique affordances for teaching and learning within metaverse.

2.2. Unique Affordances of the Educational Metaverse

Compared to traditional and online education, the educational metaverse has several unique affordances that can potentially benefit teaching and learning, including virtual identity, immersion, presence, and interaction. First, the metaverse enables learners to assume a virtual identity in the form of an avatar that can be completely different from reality. The avatar is customized and manipulated by the learners themselves, which provides them with a new kind of social presence and personalized experience (Jovanović & Milosavljević, 2022; Zhang et al., 2022). Customization of avatars can increase students' identification with the avatar character and help them build a sense of self-efficacy, which leads to higher achievement motivation (Turkay et al., 2015). According to self-perception theory, the attractiveness of an avatar enhances an individual's participation and influence in social interactions, which is particularly evident for introverted individuals (Bian et al., 2008).

Second, the metaverse provides learners with a high sense of immersion and presence. There are various virtual scenarios in the metaverse, including the university campus, natural environment, and virtual laboratories (Lin et al., 2022; Suzuki et al., 2020). These scenarios are similar to reality and can provide a sense of authenticity and vividness for students. The MR features of metaverse also allow users to coexist and interact with virtual information and avatars in real time, enhancing the sense of presence (Chen, 2022; Higgins et al., 2021). The enhanced sense of immersion and presence is known to increase students' learning motivation and encourage them to actively explore the problem space afforded by the learning environment (Ng et al., 2022).

Third, the metaverse can facilitate social interaction during the learning process. Compared with online courses delivered through video conferencing or learning management system, there are more opportunities for communication and cooperation in the metaverse. Through the embodiment of avatars, teachers and students can engage in more realistic simulated dialogues with various embedded social gestures and body movements (Kim et al., 2022). The variety of virtual scenarios and communication spaces also provide students with contextualized opportunities and means for social conversations and knowledge construction (Lin et al., 2022). We could even use advanced interaction technologies such as brain–computer interfaces in the future to enable multimodal and embodied communication in the metaverse, thus further promoting social interactions and learning experiences (Zhang et al., 2022).

2.3. Theoretical Underpinnings of the Educational Metaverse

The Community of Inquiry (CoI) framework provides a useful theoretical lens to understand the unique affordances of the metaverse and their potential for improved learning experiences. The CoI framework has been widely adopted to prescribe and evaluate learning experiences in online, blended, and multi-user virtual learning environments (Fiock et al., 2020; McKerlich et al., 2007; Stenbom et al., 2018). It consists of three interrelated elements that are considered as essential for creating meaningful learning experiences: social, cognitive, and teaching presence (Akyol et al., 2008; Garrison et al., 1999; Kozan et al., 2014). In the educational metaverse, the improved learning outcomes and experiences can be attributed to enhanced social, cognitive, and teaching presence that are enabled by its unique affordances.

Social presence is defined as the ability to project their personal identity into a community thereby presenting themselves as real people to others (Garrison et al., 1999). It is achieved in the metaverse through the creation of personalized avatars and embodied interaction with the avatar identities (Chen, 2022; Zhang et al., 2022). Cognitive presence refers to the level of cognitive engagement that allows for knowledge construction and meaning affirmation through sustained reflection and discourse (Garrison et al., 1999;

Guo et al., 2021). With its capacity to create immersive, interactive, and diverse learning scenarios and contexts, the metaverse can promote cognitive presence through student-centered pedagogies such as situated learning, experiential learning, gamification, and collaborative learning (Hwang & Chien, 2022; Jovanović & Milosavljević, 2022; Tlili et al., 2022). Teaching presence refers to the design and organization of instructional process and resources perceived by learners (Garrison et al., 1999; Kozan et al., 2014). As a digital learning environment, the metaverse provides a variety of instructional functions that support content delivery, resources distribution, learner customization, and group collaboration, and thus can lead to enhanced teaching presence (Kim & Kim, 2023).

2.4. Examples of the Educational Metaverse

Our review of the literature revealed only a few empirical studies describing the educational metaverse. For example, Jovanović & Milosavljević (2022) used mixed methods (questionnaires and interviews) to implement an engineering education course in a metaverse platform called VoRtex. Their results showed that students had an overall slightly better educational experience, and the platform's features facilitated internal communication and knowledge sharing among students. Similar studies were found in other subject domains such as English instruction and safety education (Guo & Gao, 2022; Kanematsu et al., 2014), which showed positive instructional effects and immersion. However, there have also been many empirical studies conducted in earlier versions of the metaverse, such as Second Life. For example, Jarmon et al. (2009) implemented an interdisciplinary communication course in Second Life and used mixed methods to demonstrate the effectiveness of the Second Life environment for a project-based experiential learning approach. The study found that the embodied social presence afforded by Second Life endowed students with more realistic with concrete experience, and thus initiated and enhanced the experiential learning cycle. In addition, studies implemented in Second Life were also found to promote other pedagogies, such as collaborative learning (Sutcliffe & Alrayes, 2012) and problem-based instruction (Esteves et al., 2009), with reported benefits such as improved user experience, increased learning interest, and smooth collaboration.

3. Methods

3.1. The Metaverse Platform

The metaverse platform Virbela was chosen in this study to host a virtual class. Virbela contains a campus built in a virtual world, and users can create and use their own virtual avatars to access the platform through their computers. After entering this immersive, socially connected virtual campus, users can socialize with others and attend classes in virtual classrooms. We chose this platform because it is recognized as the pioneer enterprise metaverse to support remote collaboration and has been successfully implemented to host several conferences and seminars (Virbela, 2012). In addition, this platform meets the three unique characteristics of the metaverse: shared, persistent, and decentralized. The platform is permanent and accessible to users around the world, and its teaching activities and resources are created by users.

A private space available on the platform has been used that includes three screens and teachers can upload a PowerPoint presentation on the big screen individually for teaching. Figure 1 shows the perspective of the teacher on the podium, and behind the teacher are the three large screens. The platform offers functions that can augment the senses, such as screen controls and spatial voice (see Figure 1). Students can switch between three screens and zoom in and out independently through the screen control function. When the spatial voice function is on, the sound heard becomes fainter as the distance increases. However, when this function is off, the sound can be heard clearly no matter how "far away" it is. These augmented sensory functions allow students to see the magnified screen and hear the lecture more clearly than in a real classroom, which is a particular benefit for students sitting in the back row.

In addition to the general classroom presentations, the platform is also designed to provide several functions related to classroom interaction (see Figure 1). The first is the private discussion function (see Figure 1). When the private discussion function is switched on, only users sitting at the same table can hear each other: no one else can hear them, this function guarantees the privacy of student discussions. There is also a function for raising one's hand. When a student uses this function, the teacher can clearly see a hand up icon above their avatar, so the teacher understands the student's need to communicate with the teacher. In addition to these two functions, users on the platform can clap, meditate, and dance (see Figure 1) with the click of a button, and even shake hands with others. This significantly adds to the sense of interaction and immersion.

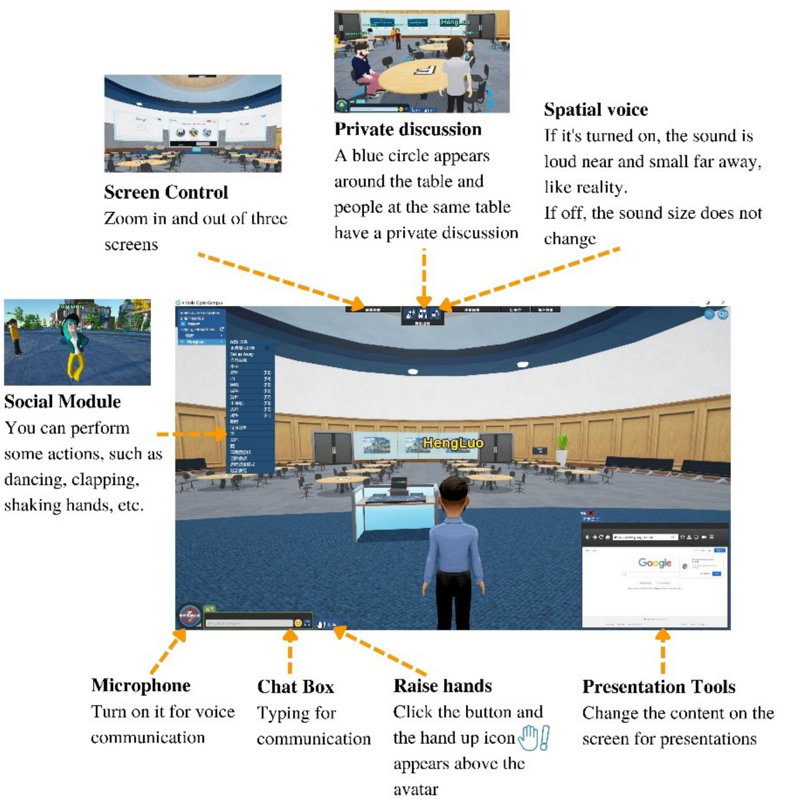

Figure 1
Screen captures of Virbela's private space and introduction to some functions

3.2. Program Implementation

3.2.1. Participants

A total of 31 first-year undergraduates from a top-tier university in central China participated in this study. The participants were recruited to attend an instructional session regarding cognitive load and multimedia learning design in the metaverse. They had never experienced learning in the metaverse and had little knowledge of the instructional contents that were to be taught in the metaverse class. The mean age of the participants was 18.42, and the gender ratio was roughly 2:1 (21 female students and 10 male students).

3.2.2. Procedure

The overall research procedure is demonstrated in Figure 2. Before the formal class, the 31 participants received a 30-minute training on the operation of the Virbela platform, including the installation and use of the platform, to ensure that they had access to the class. The participants were then divided into eight groups, each contained three to four participants. The participants were informed that they were free to choose the location from where they would attend the class, provided that the place had good internet access and access to a computer. Also, 10 minutes before the start of the formal class, the teaching assistant uploaded the PowerPoint on a screen in the middle of the private classroom and then asked the participants to enter the private space on the platform and sit in groups at different tables. The teaching assistant also conducted a short trial session to ensure that everyone could hear the teacher's voice and see the PowerPoint properly.

The formal class in Virbela lasted approximately 40 minutes and consisted of a simple lecture and a group discussion (Figure 2). First, the teacher taught about three types of cognitive load and definitions based on the PowerPoint slide presentation, and then organized a group discussion on a case study about cognitive load. The teacher turned on the private discussion function, and blue circles appeared on the ground around each table. The voices of people in the circle can only be heard in the circle and will not be heard outside (see Figure 1). During the students' discussions, the teacher stepped down from the podium and sat at different tables at random to observe the students' discussion. After 6 minutes of group discussion, the teacher returned to the podium and encouraged the students to use the hand-raising function to speak and summarize the discussion they just had. Then, the teacher gave a brief wrap-up to end the class (During the whole process, the spatial voice function was turned off to ensure that every student could clearly hear the same voice level.).

After class, all the participants were asked to fill in and submit an online questionnaire about their learning experiences. All of the participants took 40-minute knowledge tests in the computer classroom. In addition, eight participants were selected for semi-structured interviews to gain insight into their learning experience of the metaverse course.

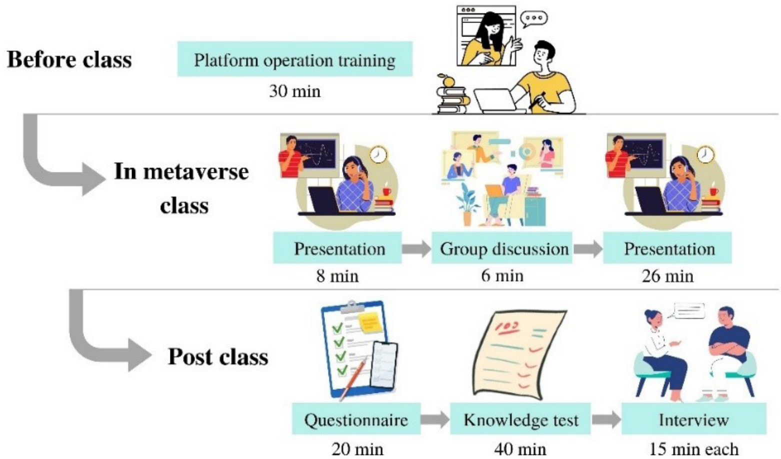

Figure 2
Research procedure

3.3. Data Collection and Analysis

3.3.1. Data Collection

First, we used observation to observe and assess the participants' learning performance and experience in the metaverse classroom. In addition, two researchers (first and third author) were placed in the metaverse space to stand at different angles and videotape the classroom process. This allowed for further observation after the class by watching the videos recording the class.

A knowledge test was used to test the instructional effectiveness of student learning in the metaverse-based class; it consisted of 10 multiple-choice questions, 10 true-or-false questions, and one operational question. The multiple-choice and judgment questions examined students' recollection of knowledge about cognitive load and multimedia design principles. The final manipulative question examined how to apply what students had just learned to revise a problematic PowerPoint slide. All of the questions were created based on the content taught in this class. The maximum knowledge test score was 100 points, which was the sum of the scores for the objective questions (60 points) and the subjective operational questions (40 points).

A questionnaire was used to examine students' learning experiences in the metaverse classroom (see Appendix A). The questionnaire consisted of 48 five-point Likert-scale items that could be divided into three sub-scales: a learning engagement scale (n = 26), which was adapted from the instrument by Gunuc & Kuzu (2015); a learning motivation scale (n = 12), which was adapted from the instrument by Lin et al. (2020); and a perceived sociability scale adapted from the instrument by Kreijns et al. (2007). The overall internal reliability of the questionnaire measured by Cronbach's α was 0.981, and the α values for the three sub-scales were 0.955 (learning engagement), 0.968 (learning motivation), and 0.962 (perceived sociability), which indicated the good instrumental reliability of the questionnaire.

A post-course interview was also used to investigate the specific learning experiences and feelings of the participants, as well as any technical difficulties they encountered. In total, eight representative students were interviewed individually, with the average time of an interview session being about 14 minutes. Some sample interview questions were as follows: "What technical functions were used and how did you feel about them?" "Please indicate any technology problems technology that affected your learning experience," and "What do you think could be improved about this metaverse classroom?" The interview process was audio recorded, and the recorded content was later transcribed for subsequent qualitative analysis. The total length of the transcript is approximately 13,600 words.

3.3.2. Data Analysis

For the analysis of the quantitative data from the knowledge test and questionnaire, descriptive statistical analysis was first used to examine the learning outcomes and learning experiences of the participants. At the same time, to investigate whether network factors and technical problems influenced participants' experience, we conducted non-parametric tests using SPSS version 25.0. The grouping of participants based on severity of technical problems encountered was used as the independent variable, and the learning experience of the participants was used as the dependent variable; Mann–Whitney U test was used to determine the difference between the two groups.

For analyzing the qualitative data obtained from the interviews and observations, we followed the thematic analysis procedure proposed by Braun & Clarke (2006). First, we familiarized ourselves with the interview transcripts and captured videos by reading or watching them at least three times before the formal coding process. Then, we generated the initial codes by mainly using four coding techniques specified in the coding manual by Saldaña (2013): (1) structural coding based on our research questions and key constructs, (2) In vivo coding that captures the vividness and authenticity of commentary, (3) versus coding that emphasizes the complexity and diversity of metaverse experience, and (4) evaluation coding that focuses on the benefits and challenges facing educational metaverse. The operational details and examples of the four coding techniques are shown in Table 1. Next, we further categorized, compared, and synthesized the initial codes to formulate themes using a more deductive approach, as the themed findings were primarily used to provide triangulation and explanation of the quantitative results. The coding and theme identification processes were based on continuous discussion and negotiation within the research team.

Table 1
Definitions, operations, and examples of the four common coding techniques used in the present study

Technique	Definition	Operation	Example codes
Structural coding	Preexisting concepts applied to data to address specific research questions	A list of preconceived theoretical constructs, such as design features, technical affordances efficacy, and learning experiences	INTERACTION, IMMERSION, HIGH TEACHING EFFICIENCY, NICE LEARNING EXPERIENCE, OFFLINE
In vivo coding	The actual verbatim phrase or word used by the participant	Indigenous terms extracted from observations and interviews to describe students' authentic learning experiences	"ENTER A NEW WORLD", "FEELS LIKE BEING IN A REAL CLASS", "FUN VIRTUAL AVATAR", "DANCING IS HILARIOUS"
Versus coding	Dichotomous codes that indicate strongly conflicting or mutually exclusive divisions	Highlighting the different perceptions of metaverse learning by participants influenced by different technical problems	ENGAGING VS. DISTRACTING, INCLUSION VS. ELUSION, FLEXIBILITY VS. RESTRAINT
Evaluation coding	Codes that assign judgments about merit, worth, or significance of programs or policy	Assessment of the strengths and weaknesses of metaverse instruction, and recommendations for improvement	PRIVATE DISCUSSION (+PRIVATE, − LACK OF TEACHER FACILITATION), REC (RECOMMENDATION): CUE THE TEACHER TO JOIN DISCUSSION

4. Results

4.1. Effectiveness of the Metaverse Learning Program

The mean scores and standard deviations for each dimension of the participants' learning experiences are presented in Figure 3. The distribution of scores is presented in Appendix A. The average scores for participants' learning experiences in each dimension were > 3 (indicating a neutral opinion). As indicated by the experience ratings above 4, students in this study reported a great learning experience in the metaverse in terms of emotional engagement, behavioral engagement, learning motivation, and perceived sociability, as well as recognizing its capacity to promote social relationships among peers. However, cognitive engagement scored slightly below 4, and there was a large percentage of students in the middle score range (see Appendix A), indicating that there is still room for improvement in the metaverse to promote students' cognitive engagement during learning. In summary, participants assessed their learning experience as generally good throughout the metaverse class.

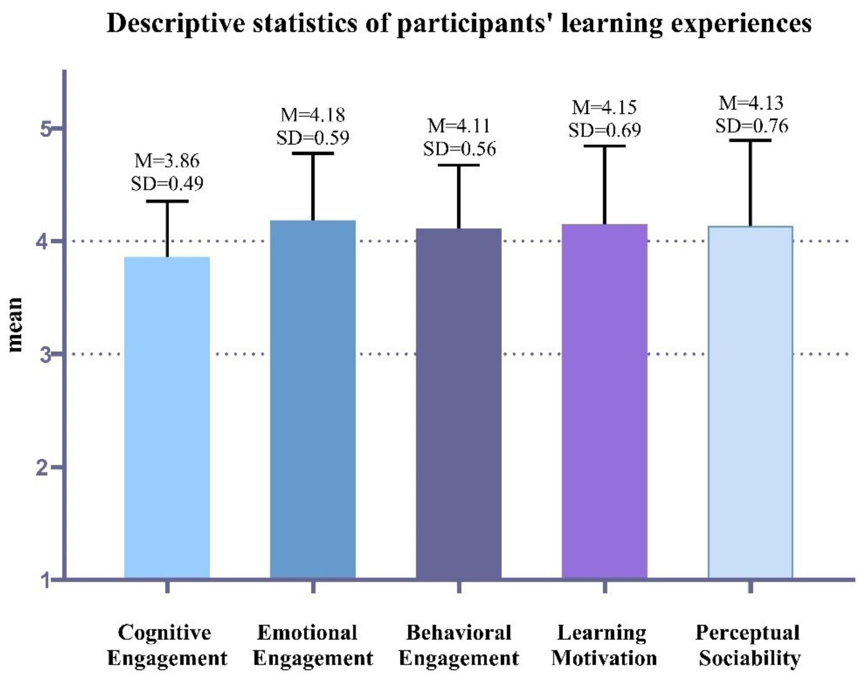

Figure 3

Descriptive statistics of participants' learning experiences

Figure 4 shows the means and standard deviations of participants' knowledge test scores (that include scores for the objective and subjective test items). The full marks for objective and subjective questions are 60 and 40 respectively. The mean score on the knowledge test was over 60, which indicates that the participants performed relatively well in terms of knowledge absorption. Participants were able to understand and remember what had been taught in the metaverse class, as evidenced by the average score of 44.65 on the objective questions. This may have been due to the metaverse teaching style was more interesting and the platform offers a better presentation of knowledge in terms of clarity and sound. However, participants had lower scores (M = 15.65, SD = 7.22) on the subjective questions, which may be because our current instructional design in the metaverse classroom was more suited to knowledge memorization but lacked instruction that would foster higher-order thinking, such as hands-on activities. Overall, the knowledge test scores were not very satisfactory.

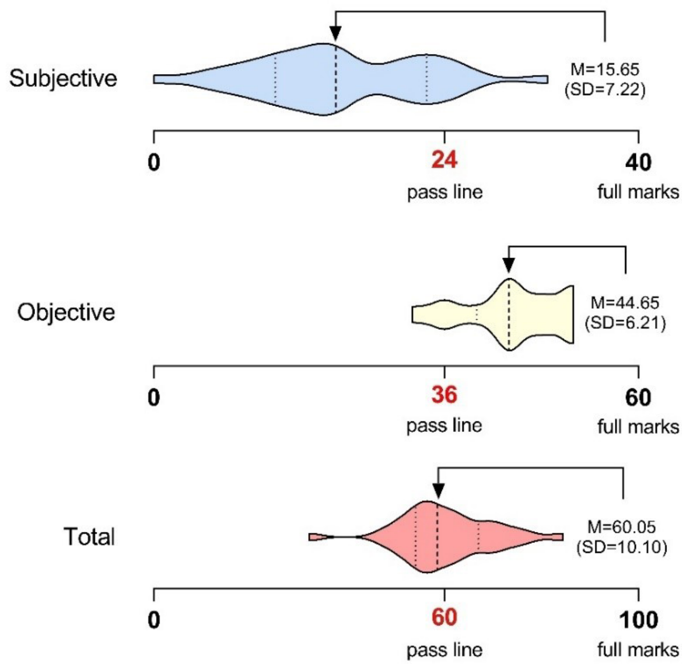

Figure 4

Descriptive statistics of metaverse learning outcomes as measured by knowledge test scores.

Note. 24 points indicate the pass line for the subjective test, 40 indicate the pass line for the objective test, and 60 points indicate the pass line for the total test.

The qualitative data also provided additional evidence of the instructional effectiveness of this learning program. Based on the interview data, participants generally agreed that they felt more engaged and immersed in the metaverse class than in the average online class. For example, one participant expressed that engagement in the metaverse was better than a Tencent meeting (the most popular video conferencing tool in China), which was the equivalent of watching a video that one becomes quickly tired of watching. In addition, the on-screen controls and the spatial voice function were mentioned several times by participants, as both reduced their learning burden and enabled them to absorb knowledge easily and quickly. However, based on observation data, we noticed some participants' attention may not have been on the class but on the platform function, as some students would perform irrelevant actions such as dancing and clapping in class. We believe these actions may be because they perceived it as a novelty effect. Therefore, the novelty effect may also be responsible for certain participants' low scores on the knowledge tests.

4.2. Learner Perception of Metaverse Design Features

The qualitative data revealed participants' perceptions of and attitudes toward the design features of the metaverse platform. The overall metaverse experience was quite positive, as the participants used words such as "fun," "high-tech," "immersive," "innovative", and "interactive" to describe their metaverse learning experience. However, the participants also discussed the issues they encountered during the learning process and attributed those issues to certain design features of the metaverse platform. Based on our coding results, we identified the top four metaverse design features frequently used by the participants and summarized their advantages, disadvantages, and proposed improvements in Table 2.

Table 2

Participants' perceptions of metaverse design features

Design features	Advantages	Disadvantages	Improvement suggestions	Usage frequency
Virtual avatar	• Enhanced individual presence; • Reduced shyness due to virtual identity	• Lacking facial details; • "Not pretty enough"	More avatar templates with enhanced customizability	100.0%
Private discussion	• High level of privacy • Less distraction; • Fun way to interact with peers; • Relaxing atmosphere	• Lack of teacher facilitation; • Absence of moderation	Added function to cue teacher and indicate discussion end	100.00%
Screen control	• Augmented visual and audio perception • Customized viewing experience; • Enhanced immersion	• Occasional crashes; • Unintuitive operation	Enhanced stability and usability	90.00%
Dancing & clapping	• Great fun; • Enhanced interaction; • Greater social presence	• Too loud; • Distractive and disruptive to learning	Specify time and spaces for those functions	50.00%

The function to modify virtual avatars was liked by almost everyone, and we observed that everyone entered the class with a brand-new virtual avatar (not the default). Many of the participants thought the process of designing their own virtual avatars was very interesting and satisfying, and they were also impressed by the virtual avatars of other participants: "It was like they were right in front of me in another new avatar, and I no longer felt shy when talking to them." However, some participants also expressed a desire for their virtual avatars to be more selective and more beautiful.

The private discussion function was also very popular and was used by all participants. This function ensured that their group discussions were private, allowing them to be more vocal about their views without being heard by other groups or teachers. "However, it would have been nice if we were given a closing sound effect at the end of our discussion session so that the sound was not suddenly externalized to the whole class," said one participant. Some participants also expressed a desire for teachers to join the discussion and for there to be a simpler function to cue teachers to join their discussions.

The platform's "screen control" function was used by 90% of the participants, which made their classes more convenient. As they could use three screens to view the PowerPoints, it felt like they were in a real classroom. They could zoom in and switch between the three screens on their own, and the screen display was clearer than most classroom formats such as Tencent Meetings or offline classes.

Social functions such as dancing and handclapping were perceived as quite fun by the participants. These functions enhanced a great sense of social presence and promoted peer interaction in the educational metaverse, which are essential for increasing and maintaining students' learning motivation. However, many participants also complained that too much dancing and clapping could be distracting and disrupt the classroom with unnecessary actions and noises.

4.3. Technical Challenges to Metaverse Instruction and Its Impact on Learning

Table 3 shows the frequency of the main technical problems encountered by the 31 participants during the metaverse instruction. Network drops occurred most frequently, and many participants' learning experiences and outcomes were largely affected by this problem, making it an urgent issue. Sound issues were another challenge, as many participants reported that they could not hear others' voices clearly or be heard in turn. Fewer participants encountered the issues of the audio and video being out of sync or the presentation not displaying.

In addition to the quantitative data, the qualitative data also revealed the disruption caused to participants by network problems. Half of the participants had a very smooth internet connection and were online during the metaverse class, but the other half were having problems with network drop (to varying degrees). One participant commented, "The network problems affected my experience too much, as the network was bad, and I sometimes lost connection and could not listen to what the teacher was saying."

Table 3

Technical problems encountered by participants.

Frequency	Network drops	Sound issues	Out-of-sync	Presentation display issues
Once	3 people	5 people	2 people	1 person
Twice	2 people	3 people	2 people	0 people
Three times	2 people	2 people	1 person	0 people
Four times	11 people	2 people	2 people	1 person

To explore the impact of technical problems on the learning of participants, they were divided into two groups according to the number of technical problems they encountered: groups with more technical problems and those with fewer technical problems. We then compared these two groups regarding the participants' questionnaire scores on the three dimensions of learning engagement, motivation, and perceived sociability. The main results are shown in Figure 5. Overall, there were no significant differences between the two groups on these three dimensions, suggesting that technical problems had little impact on the overall learning experience of the participants. However, network drop problems seemed to have a more prominent impact on the participants' learning experience, as seen in Figure 6. Although there was no significant difference between the scores of each of the two groups, the group with more network drop problems scored somewhat lower than the group that did not experience this problem. Separately, participants' learning motivation (MD = −0.34, U = 84.000, Z = −1.430, p = 0.153) was least affected by the network drop problem, while learning engagement (MD = −0.36, U = 74.500, Z = −1.803, p = 0.071) and perceived sociability (MD = −0.36, U = 75.000, Z = −1.820, p = 0.069) were more affected.

Surprisingly, there was no significant difference in the students' learning experience dependent on technical problems or network drops. Network issues showed a greater impact on the learning experience, which reveals the importance of ensuring network smoothness in future practice and research. The high number of network drops in this study may be because we used the campus internet, and the public internet is known to suffer from lower and more unstable speed.

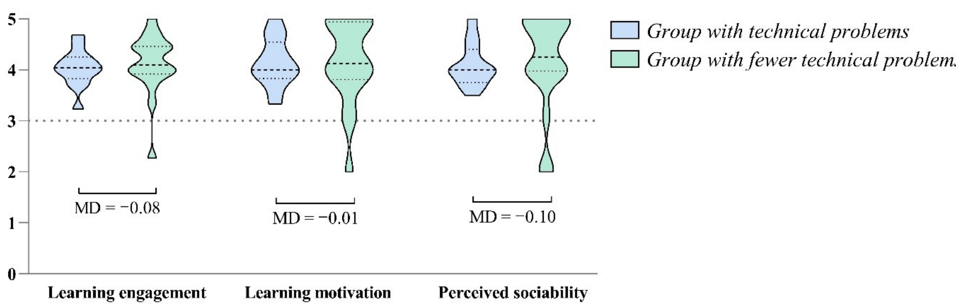

Figure 5

Differences between groups with more technical problems and those with fewer technical problems

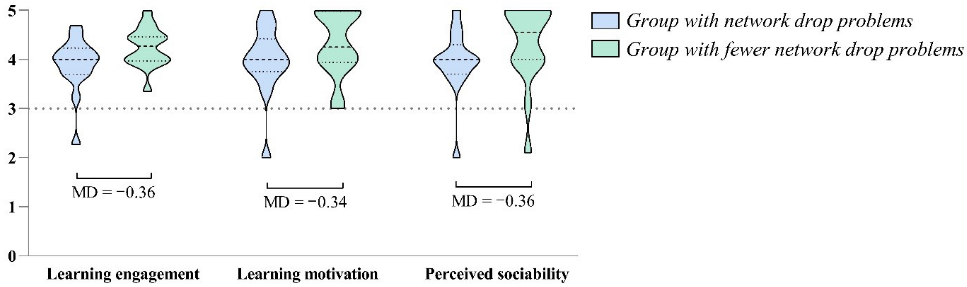

Figure 6
Differences between groups with more offline problems and those with fewer offline problems

5. Discussion and conclusions

To explore the effectiveness of metaverse technology applied to instruction, this study collected both qualitative and quantitative data, which yielded three conclusions. First, our results revealed that students had a good learning experience in the metaverse, while their learning outcomes were less satisfactory. There are several possible explanations for this result. It may be related to the variance in social, cognitive, and teaching presence. The social functions and teaching venues afforded by the platform may have given students a high perception of social presence and teaching presence, thus enhancing their motivation and experience of learning. However, the cognitive presence in the educational metaverse might suffer from the teacher-centered instruction and insufficient group discussion time, which failed to result in an increase in higher-level thinking, such as problem-solving and critical reflection. The unsatisfactory learning outcome in the educational metaverse could also be explained by the novelty effect, although novelty may enhance students' interest, but it can also distract students and cause disruptions to their learning.

Second, the metaverse functions received diverse reviews. Most interaction functions were well received by the students. A possible explanation for this might be that the interaction between virtual avatars was effective in enhancing social presence and immersion (Davis et al., 2009). Another possible explanation is that these useful interactive functions enhance cognitive presence, for example, private discussions enhance immersion, thus enabling students to invest more cognitive resources and increase motivation. Technology-enhanced functions were also relatively well received. This finding may be explained by the fact that these functions enabled a better-than-reality learning environment, thus enhancing teaching presence and making learning more convenient. For example, in a realistic classroom environment, not everyone can see what is projected so clearly.

Third, although students encountered various technical problems during their learning process in the metaverse, the issue of network drop was encountered more often and had a greater impact on the learning experience. There are two possible explanations for this result. First, the students did not develop excessive negative feelings towards the technical problems due to the novelty effect. However, a matter of concern is if students are learning in the metaverse for the long term, these problems may become very disturbing to them. Second, students' previous online learning experiences may have given them more mental preparation for a common technical problem. Regarding network drops, a possible explanation for this might be that the network dropping out directly caused the student to be disconnected from the learning environment and required very tedious operations and longer periods before they could return to class.

5.1. Implication for Teaching and Learning in the Educational Metaverse

The findings of this study have important implications for teaching and learning in the educational metaverse. Teachers need to conduct pre-course training, allowing students to test their computer capacity and network conditions so that technical issues might be avoided during formal instruction. Teachers should also explore the instructional model and strategies proper for the metaverse learning environment. The mediocre test scores in this study suggest that the lecture-based approach failed to improve learning outcomes even in the metaverse environment. The unique social functions of the metaverse platform should be further utilized to enable student-centered collaborative pedagogy. Finally, teachers also need to set rules in advance that would prohibit students from disrupting the class with untimely dancing and clapping.

For students, they need be physically and mentally prepared for studying in the metaverse. Students should find a suitable physical environment that is quiet and private, with fast internet, so that they can make smooth and comfortable conversations with other virtual characters without fear of disruption and embarrassment. They also need to be more proactive in utilizing the unique functions of the metaverse such as private spaces, virtual displays, and presentation controls to achieve maximum benefits. Moreover, students should also anticipate the problems associated with the metaverse, and when encountering technical issues, they should remain calm and continue their learning regardless.

For platform designers, more improvements are needed for the metaverse platform. First, we believe that the metaverse platform should make more technical improvements in terms of network drops and lag. Second, functions need to be practical and technically stable. Certain functions are welcomed by students, but they might also cause distraction during learning, so they should not be prioritized during platform development. Finally, future metaverse platforms should include more functions that support diverse pedagogies—such as collaborative learning, simulated experiment, and game-based learning—in addition to lecture-based instruction. Desirable functions to be added include annotation, assignment submission, peer assessment, virtual lab, game scenarios, and gamification features (e.g., ranking, experience point systems, competitions).

5.2. Limitations and Future Research

Three major limitations in this study should be addressed in future research. First, the research findings were susceptible to novelty effects, because the study was conducted only once for 40 minutes. Whether the learning experience and outcomes might change after the novelty effect wears off is yet to be verified. Second, the study was conducted with one course and for a specific instructional topic in cognitive psychology, so it remains to be investigated whether the findings are applicable to other instructional contexts and subject areas. Finally, only the traditional measurement approaches such as tests and questionnaires were used to measure the key constructs in this study. The inherent limitations of those approaches might undermine the credibility of the statistical results. Therefore, we suggest that future studies should implement a metaverse intervention for a prolonged period to exclude the novelty effect, replicate the study in more diverse instructional contexts, and use diverse research instruments to collect multimodal learning analytics (e.g., clickstream, virtual gestures, and verbal communications).

6. Funding

This research was funded by the National Natural Science Foundation of China [grant number 62177021], and the Hubei Provincial Teaching and Research Project for Higher Education (Hubei, China) [grant number 2020709].

7. Appendix A: Score distribution of participants' learning experience questionnaire

Please click on this URL to view: https://doi.org/10.17632/cj2xmwbwrx.1

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