Exploring the Potential of Immersive Technology for Virtual Teaching and Learning: A Metaverse Conference Experience

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***Abstract*—The outbreak of COVID-19 has accelerated the adoption of virtual teaching and learning in education. Metaverse, an immersive platform that merges physical and digital realms, has become the center of attraction. The opportunities and challenges of Metaverse for teaching and learning have been widely discussed. Existing literature suggests that Metaverse can enhance students' engagement and provide an immersive learning experience in a classroom situation. However, there is limited research focusing on the application of Metaverse in a teacher-centered learning environment. In this study, we organized a real-time conference and showcase exhibition in the Metaverse platform powered by Mozilla Hubs. The session was broadcasted simultaneously via Zoom. A survey was conducted after the conference to collect participants' feedback. By comparing the users' experience on Metaverse with Zoom and assessing the organizers' insights, this study sheds light on the importance of having a tailor-made setup to accommodate teacher-centered learning needs in the Metaverse. Second, participants might feel disconnected from each other with the use of cartoon-shaped avatars. It is noteworthy that facial expressions and body movements are essential for developing social presence. Third, it is vital to provide adequate user training to get users familiar with the Metaverse platform.**

***Keywords*—immersive technology, Metaverse, education, virtual teaching and learning, virtual world**

I. Introduction

The rapid advancement of technology has transformed the landscape of education, with virtual teaching and learning becoming increasingly popular. The COVID-19 pandemic has further accelerated this trend, as educational institutions worldwide have been forced to adapt to remote learning. As a result, there is a growing interest in exploring innovative technologies that can enhance the virtual learning experience and overcome the limitations of traditional online platforms.

One such technology is immersive technology, which has the potential to revolutionize the way we meet and communicate in virtual environments. Immersive technology, such as Virtual Reality (VR) and Augmented Reality (AR), can provide a more engaging and interactive experience by simulating real-world environments and enabling users to feel a sense of presence. Metaverse platform, just like the one powered by Mozilla Hubs, is an extension of immersive technology. It can be considered as the "virtual reality existing beyond reality" [1]. Educators have started to integrate the Metaverse technology into traditional education. As Zhang *et al*. [2] suggested, Metaverse for Education can be defined as "an educational environment enhanced by Metaverse-related technologies which fuse with the elements of the virtual and the real educational environment." The unique like-real environments of Metaverse can create a student-centered learning environment [3] and provide a comprehensive learning and social experience for students learning [4].

The application of Metaverse is usually more focused on the peer learning experience that involves participants freely conversing with each other in the virtual environment. It is likely a result of the social-oriented nature of most Metaverses being designed nowadays—they are designed with a heavy social orientation to facilitate individuals meeting and conversing with each other. A big question thus remains whether such an environment can also facilitate different kinds of virtual teaching and learning activities that are more teacher-focused and resemble more what happens in a physical classroom. Such learning activities are essential if we consider the virtual world a comprehensive learning environment covering both learning opportunities.

Given this, we would like to address the following research questions through the experience of organizing a conference on the Metaverse platform:

R1) Can a typical Metaverse be used to facilitate a teacher-focused type of learning experience based on the views of the participants?

R2) Can the benefits mentioned in the literature also be found in this teacher-focused usage, namely, increased motivation of the students, and whether students found they are more engaged in interacting with their peers?

R3) What are the challenges of using Metaverse in a teacher-focused context? Are the challenges in line with those commonly reported in past studies?

II. Literature Review

The potential benefits of immersive technology for virtual teaching and learning have been widely discussed in the literature. One of the advantages is the increased motivation and engagement that immersive environments can foster [5]. In particular, students are required to address the problems in a more authentic learning environment, which can help them acquire knowledge efficiently [6]. Moreover, the Metaverse environment enables users to control their unique avatars and undertake embodied actions in both verbal and non-verbal formats [7]. The lifelike environments and interactive features of Metaverse platforms also create a more stimulating learning experience in which students can have the freedom to conduct self-directed learning [1, 8].

Secondly, by providing a realistic and immersive environment for teaching and learning, Metaverse can facilitate situated learning and demonstrate near-transfer

knowledge in disciplines like surgical study and anatomy education [5, 9]. Teachers can also create realistic 3D models to provide a stronger sense of place presence for students using both VR headsets and PCs [10]. Moreover, Metaverse enables students to explore inaccessible environments, such as historical heritage and outer space, as well as to improve students' conceptual understanding [3, 11]. For example, Falah *et al*. [12] applied Virtual Reality (VR) technologies in anatomy education, which demonstrated a potential to enhance the visualisation of anatomical structures, facilitate accessibility and serve as self-directed learning tools.

Thirdly, virtual environments can encourage students to interact with their peers and achieve collaborative learning. For example, Tarouco *et al*. [13] implemented a Virtual Learning Laboratory in a calculus course to support group collaboration, which demonstrated a positive result in fostering teamwork. The comfortable and immersive nature of the virtual platform can encourage students to stay behind after formal teaching sessions, facilitating valuable peer-to-peer interactions and fostering a sense of community [14]. Moreover, there are interactions between different participants but also between participants and computer-controlled avatars in the virtual environment [5, 8].

On the other hand, the knowledge level of the users regarding the rapid advancement of technology can be a limitation. Educators may need more faith and understanding to effectively apply immersive technology in teaching [15]. Adequate preparation and detailed instructions are also required to ensure students can make the best use of the new tools [16, 17].

Controlling students' behavior in the Metaverse is also a great challenge, as they enjoy a high degree of freedom [1]. According to Kye *et al*. [1], users can hide their identity and create anonymous avatars, allowing them to become a version of themselves that they want to present. The freedom to not expose real-world identity may reduce the sense of guilt about inappropriate behavior or even crimes.

III. Methodology

A. Conference Platform Design

In June 2023, we hosted a cross-institutional exhibition titled the "*Virtual Teaching and Learning Innovation Expo in the Metaverse*" in a web-based Metaverse platform powered by Mozilla Hubs. The exhibition showcased five real-time keynote speeches by scholars from Hong Kong and Australia, as well as 30 pre-recorded presentations from six higher education institutions in Hong Kong. The live sessions were conducted on Mozilla Hubs and simultaneously broadcasted via Zoom. Furthermore, the exhibition platform remained accessible beyond the live event day, allowing participants to access the pre-recorded presentations at their convenience. Participants who attended the conference in the Metaverse were able to navigate the virtual environment, interact with other attendees using their avatars, and engage in the conference activities. Meanwhile, participants who attended the conference via Zoom were able to view the live stream of the event and participate in the discussions through the chat function.

The decision to host the exhibition on Mozilla Hubs was driven by its accessibility, as participants could easily access the platform via their desktop or mobile browser. Additionally, participants had the option to use VR devices for a more immersive experience. However, due to the maximum participant limit of 25 and geographical restrictions to the UK, USA, Germany, and Canada, we opted to build our own hub on a private server. This allowed us to operate the hub in Hong Kong and accommodate more participants in real time.

To address the need for live presentations, we have customized the virtual platform to make it more teacher-centered in terms of functionality. One crucial feature is the utilization of Audio Zones, which ensures that speakers can be heard clearly throughout the entire space, regardless of the participants' positions. In addition, participants' microphones have been adjusted to optimize sound levels, restricting conversations on the floor to a specific area and minimizing interference with the teaching process. We have further implemented the Audio Zones feature and created a backstage area for speakers to engage with each other without affecting the front stage. Virtual notices were strategically placed within the virtual space as reminders to ensure that participants did not access the backstage.

Training sessions have been organized for speakers, and a user guide has been prepared for all speakers. The training sessions aimed to familiarize speakers with the Metaverse platform and its unique presentation features. Before their sharing, we would help to set up the presentation materials using the pre-designed Media Frame feature. During the presentation sessions, speakers can quickly flip through their PowerPoint slides with the "Presenter View" panel shown in front of them (Fig. 1). Alternatively, we can assist speakers by playing videos or controlling slides on their behalf.

Fig. 1. The "Presenter View" panel.

We created three Metaverse scenes on our hub, including the lobby (Fig. 2), the main stage (Fig. 3), and five exhibition halls with different themes (Fig. 4). The lobby served as the entrance and provided a space for social interaction. Once participants entered the lobby, they could choose to attend the live keynote sessions or explore the 30 showcases in the exhibition halls. For the interior design, we utilized both our own custom-built 3D models and open-source models from Sketchfab. Furthermore, we implemented unique features such as a messaging function, which allowed participants to leave messages for individual pre-recorded presenters. Each exhibition hall also had message boards where participants could share their thoughts, comments, and questions. In terms of inclusivity, we created a diverse range of avatars for

participants to choose from, representing different genders, ethnicities, and skin colours.

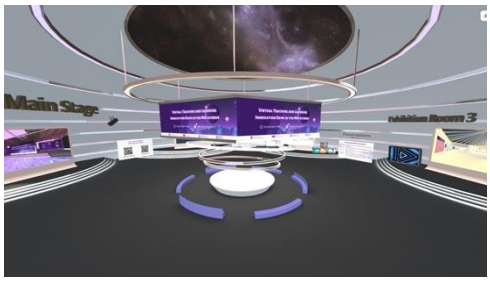

Fig. 2. The lobby of the conference platform.

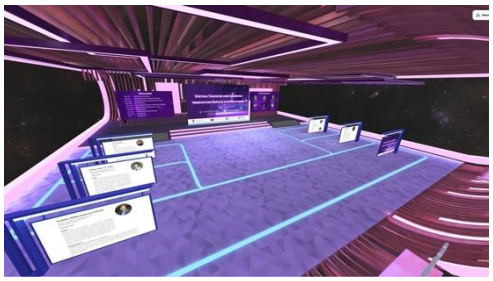

Fig. 3. The main stage of the conference platform.

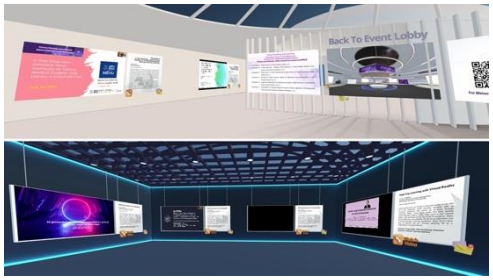

Fig. 4. The exhibition halls of the conference platform.

B. Participants

Participants in this study were professional and research-supporting staff in the higher education sector. Three groups of participants were included to ensure a fair comparison between those who were fully immersed in the Metaverse environment and those who attended the conference through a traditional online platform:

1) 50 participants who participated in the conference as avatars in the Metaverse.
2) 80 participants who viewed the live stream on Zoom simultaneously.
3) 6 presenters who delivered live presentations in the Metaverse.

Fig. 5 is a screen capture showing the activity in action.

Fig. 5. The talk in action.

C. Survey Design

Following the conference, participants were invited to complete a Likert scale survey about their experiences and perceptions of joining the event in the Metaverse or on Zoom. The survey included both close-ended and open-ended questions about the perceived advantages and challenges of using immersive technology for teaching and learning, as well as the participants' overall satisfaction with the conference. The survey also collected demographic information, such as age, gender, and educational background, to better understand the characteristics of the participants.

In total, we received 12 responses from Metaverse participants, 9 responses from Zoom participants and 3 responses from the speakers. In addition to the surveys, the research data also incorporated reflections from the conference organizers in a post-event meeting.

IV. Result

A. Survey Result

The survey results indicate participants' attitudes towards using Metaverse and Zoom in a teacher-centered environment, respectively. Half of the 12 Metaverse participants agreed that they felt connected with the speakers, while only 33.3% (4 out of 12) agreed they felt connected with other participants. Moreover, only a minority of Metaverse participants (33.3%) agreed that connecting with other participants in the Metaverse was easy. The survey result is in line with the organizers' observation that participants seldom interact with each other in the virtual environment. In addition, as shown in Table 1, it is noteworthy that in terms of "connectedness with speakers and other participants", "sense of community", "overall learning experience", as well as "preference for future events", Zoom participants have a higher satisfaction rate than Metaverse participants.

Table 1. Responses from Metaverse and Zoom audiences

Question	Metaverse participants (N=12) Mean (SD)	Zoom Participants (N=9) Mean (SD)
I felt connected with the speakers while attending the event in the Metaverse (on Zoom).	3.25 (1.29)	4.00 (0.71)
I felt connected with other participants while attending the event in the Metaverse (on Zoom).	3.17 (1.34)	4.00 (0.71)
I felt that the Metaverse (Zoom) environment facilitated a sense of community among participants.	3.25 (1.22)	4.11 (0.60)
It was easy for me to connect with the speakers in the Metaverse (on Zoom).	3.00 (1.21)	3.89 (1.05)
It was easy for me to connect with other participants in the Metaverse (on Zoom).	3.00 (1.28)	3.78 (1.09)
The Metaverse platform (Zoom) enhanced my learning experience compared to traditional video conferencing platforms like Zoom (more immersive platforms like the metaverse).	3.25 (1.48)	4.11 (0.60)
I prefer attending future events in the metaverse over traditional video conferencing platforms like Zoom (on traditional video conferencing platforms like Zoom over the Metaverse).	3.08 (1.31)	3.56 (1.13)

Notes: () = Zoom participants survey wording; The 5-point Likert scale is used (from 1 = strongly disagree to 5 = strongly agree)

Five of the Metaverse participants (41.7%) either disagree or very disagree that the Metaverse platform can enhance their learning experience when compared to Zoom. They stated that one of the significant challenges is technical difficulties, for instance, a participant cannot play the pre-recorded video in the Metaverse platform. Another major challenge is people feel alienated from each other. "*I did not feel the connection with the speaker as I do in a Zoom session where I can see the actual face of the speakers*," said a Metaverse participant. This finding is consistent with prior research that since the cartoon-shaped avatar in Mozilla Hubs cannot reflect users' emotional expression, participants may feel less co-presence when compared with Zoom [10].

The strengths and weaknesses of teaching and learning in Metaverse and Zoom identified by the participants are summarized in Table 2. By comparing the user feedback on Metaverse and Zoom, we understand that although Metaverse has the potential to provide a more immersive learning experience, there are still lots of technical problems that need to be taken into account to improve the user experience, in particular, the importance to have real-time feedback and facial expression.

Table 2. Strengths and Weaknesses of teaching and learning in the Metaverse/on Zoom

	Teaching and Learning in the Metaverse (open-ended remarks by participants in the Metaverse)	**Teaching and Learning on Zoom (open-ended remarks by participants in Zoom)**
Strengths	• Provide a sense of presence and sense of immersive • More attractive and creative • Increase student engagement • Closer interaction with other participants • Provide an experience closer to physical attendance compared to Zoom • Free from location barriers and time zone differences	• Easy to use (i.e., teachers are more familiar with Zoom features) • More stable and better sound quality compared to the Metaverse • Better student collaboration as they can have group discussion using the Breakout Room function • Better concentration • Free from location barriers
Weaknesses	• Less interaction and appropriate feedback • Alienation (i.e., unable to see each other) • Technical difficulties and network problems (e.g., pre-recorded videos could not be played successfully) • Lack of technical support and resources	• Not as immersive and interactive as the Metaverse and face-to-face events • Technical difficulties and network problems • Less freedom for self-directed learning

In addition, we have collected feedback from the speakers about their overall experience and the technical barriers they encountered before or during the event (Table 3). Two of the three respondents agreed they prefer to present in the Metaverse over a traditional video conferencing platform. They mentioned that *"It was quite immersive and fun, giving a new dimension to the talk. Using avatars removes the physical considerations from presenting, allowing speakers to focus purely on the content and not their appearance and presentations,"* and "*The Metaverse can provide more alternative ways to interact. I think it should go beyond virtual presentation."*

Table 3. Responses from the speakers

Question	**Keynote Speakers (N=3) Mean (SD)**
Presenting in the Metaverse enabled me to communicate my ideas effectively.	3.67 (0.58)
Presenting in the Metaverse allowed me to engage the participants effectively.	3.33 (0.58)
I felt connected with the audience while presenting in the metaverse.	3.33 (1.53)
I felt that the audience was engaged and responsive during my presentation in the Metaverse.	3.33 (0.58)
The Metaverse platform allowed me to facilitate a sense of community among participants.	3.33 (1.53)
I prefer presenting in the Metaverse over traditional video conferencing platforms like Zoom.	3.33 (1.15)

The 5-point Likert scale is used (from 1 = strongly disagree to 5 = strongly agree).

On the other hand, we received similar feedback that the presenter would like to see the audience's facial expressions. "*I am not able to gauge audience engagement through facial expressions and body language (or verbal feedback when I would normally expect a few laughs)*," said the speaker, who rated 2 for feeling connected with the audience while presenting in the Metaverse.

Moreover, it is worth mentioning that the speakers emphasized the importance of teacher training. One speaker pointed out, "The familiarity of all participants with Metaverse interaction made it quite challenging; this will improve as people become more familiar with different Metaverse settings." Another speaker also highlighted that teacher training, along with administrative and technical support, are potential challenges for teaching in the Metaverse. Furthermore, they encountered several technical barriers during their presentation:

- *"The video that was a part of my presentation played on repeat in my ears throughout the entire presentation. My slides advanced sporadically and disappeared a few times."*
- *"Some connection and disconnection issues and the movement of guests affected the presentation slides."*
- *"The presentation slides keep disappearing. As an audience, the screen is being blocked by people in the front."*

B. Organizers' Insights

Upon reviewing the valuable feedback provided by the participants, the organizing team engaged in an internal reflection process and identified several areas for improvement. Firstly, despite our efforts to make all necessary changes to the technical component, we observed that the administrative functions needed improvement. This limitation posed challenges in effectively managing the conference and addressing unexpected issues. For example, some participants engaged in disruptive behavior by playing with the display panel while the speaker was presenting. This behavior proved annoying and detracted from the overall experience for both the speaker and the audience. While we attempted to address this issue by posting mass announcements in the Chat Box to advise the audiences, we recognized the need for more robust administrative controls to prevent such disruptions in the future.

Another observation was the limited interaction among

participants in the common areas. Although some participants visited these areas before or after live presentations, they tended to browse in solitude without actively engaging in conversations with fellow participants. This lack of interaction hindered the potential for networking and knowledge sharing during the event. Furthermore, technical problems emerged as a notable challenge throughout the conference, with some participants experiencing unexpected platform disconnections.

Lastly, we noted a significant variation in speakers' experiences, in which some speakers encountered difficulties manipulating their avatars and navigating to specific spots on the main stage. It became apparent that some speakers faced challenges due to their unfamiliarity with the features of the Metaverse platform. Consequently, their presentations did not go as smoothly as anticipated. This observation is aligned with the prior research by Ariza-Montes *et al*. [18], which emphasised that if sufficient technical support and resources are provided, users will tend to become more open-minded on the adoption of the Metaverse platform. In light of this, we recognized the importance of providing comprehensive training sessions to support our speakers.

V. Discussion

The three research questions are revisited below based on the findings.

R1: Can a typical Metaverse be used to facilitate a teacher-focused type of learning experience based on the views of the participants?

From prior research and the participants' feedback, we understand that there were a vast number of possible benefits to using the typical Metaverse for teacher-focused learning activities. For example, a respondent mentioned, "*It is a good simulation of a physical event. I feel that I have accompanied during the process."*

However, the actual experience was not as positive as the potential of the ratings given by the Zoom goers. Participants expressed mixed views regarding the suitability of the Metaverse for this purpose. While some participants found it to be a promising platform, others highlighted various challenges and constraints. These limitations include technical issues, limited administrative functions, and the need for participants to acquire new skills to navigate and utilize the Metaverse effectively. One of the Metaverse participants shared, "*For less tech-savvy people like me, it may be difficult to make the most of the session. I kept using my mouse to move, and no matter what I did, I couldn't move ahead to the main stage. Hence, I switched to Zoom, which was more familiar*." Another participant also decided to switch to the Zoom platform, which has better voice quality and less time lag. In an online lesson conducted by Eriksson [19] on Mozilla Hubs, similar technical problems were observed. Participants found the resolution of the presentation slides was low, and the poor audio quality made it hard to hear the teachers' presentations.

Therefore, although the Metaverse shows promise, it is important to address these limitations to ensure a smoother and more effective teacher-focused learning experience. In particular, it is recommended that pre-training sessions should be provided to help both teachers and students to make themselves familiar with the primary function [17]. This is in line with one participant who commented, "*I attended both platforms (Metaverse and Zoom) …Since I haven't been to Metaverse as much as I was in Zoom, it's easier for me to navigate Zoom features then. I think the Metaverse needs more exposure and promotions so people can get used to it further.*"

R2: Can the benefits mentioned in the literature also be found in this teacher-focused usage, namely, increased motivation of the students, and whether students found they are more engaged in interacting with their peers?

The answer to this question is not a simple yes or no. Some participants reported that compared to Zoom, the creative and immersive nature of the Metaverse platform can increase their motivation for engaging in the activity. They felt a sense of presence and found the platform to be visually appealing.

On the other hand, when it came to interaction, the findings were less positive. Participants felt somehow disconnected because of the lack of facial expressions and non-verbal cues that are essential for effective communication. "*I feel connected with speakers on Zoom when they turn on their camera*," said a respondent. A similar finding has been identified by Yoshimura and Borst [20]. They have implemented the Mozilla Hubs in a remote lecture. Based on the student comments collected, it is suggested that students would like to have a more "alive" teacher or presenter avatar, which can show body language and mouth movement.

In addition, from the participants' self-report and the organizers' observation, most of the participants lack connection and engagement with their peers, indicating that the Metaverse may not facilitate peer interaction as effectively as desired. The use of avatars can be a barrier for people to find each other as they might use the randomly assigned avatar outlook and name [19]. These findings suggest that while some benefits can be found in a teacher-focused usage of the Metaverse, there are still challenges to be addressed in terms of fostering meaningful interaction and engagement among participants.

R3: What are the challenges of using Metaverse in a teacher-focused context? Are the challenges in line with those commonly reported in past studies?

The challenges for using Metaverse in a teacher-focused context align with some of the difficulties commonly reported. Participants in this study highlighted the need for extensive preparation and the acquisition of new skills to utilize the Metaverse platform effectively. For example, teachers need to be familiar with how to set up and control the teaching materials. It is worth noting that these challenges can be even more pronounced in teacher-focused usage compared to social usage of the Metaverse. This finding is consistent with previous studies that have emphasized the importance of teachers acquiring technical skills and becoming familiar with the platform to integrate it into their educational practices effectively. Navigating and interacting in Metaverse environments may require a learning curve, which could initially hinder the effectiveness of teaching and learning [21].

Another challenge identified by participants was the difficulty of controlling the learning environment in the

Metaverse. The lack of control can make it challenging for teachers to manage the flow of the session and ensure a smooth learning experience for their students. This finding aligns with prior studies that state that managing the learning environment and ensuring students' concentration and active participation in virtual platforms are unique challenges for teachers.

Apart from the above challenges, it is noteworthy that several potential difficulties might be encountered if the Metaverse is to be accessed through VR headsets. Previous studies have reported that users may have cybersickness symptoms, such as headaches, dizziness, and fatigue, in the virtual environment [22, 23]. In a study conducted by Allcoat and von Mühlenen [24], they evaluated the effects of VR headsets in undergraduate education. Although students generally had a positive attitude toward using VR headsets, they pointed out that trial sessions should be provided before actual usage. However, in this study, we didn't ask the participants to indicate the tools used to access the web-based Metaverse platform, and this potential drawback was not investigated.

Another significant concern is the need for more specific functions tailored for educational communication in Metaverse platforms, which are often designed primarily for social purposes [25]. Jamon suggests that providing more user-friendly functions for teaching and learning, such as ready-made objects and easy-to-use media streaming tools, is essential. This is supported by Lee *et al*. [26], who emphasized that the usability of immersive technology platforms plays a vital role in influencing the learning and teaching experience. Furthermore, educators face challenges related to network traffic when using Metaverse in education [27]. Unstable connections and inadequate interface designs would increase learners' cognitive load [28].

VI. Conclusion

In this study, we explored the potential of immersive technology, specifically Metaverse environments, for virtual teaching and learning. By organizing a conference in a Metaverse environment powered by Mozilla Hubs, we gained valuable insights into the benefits and challenges of utilizing immersive technology in education.

On the whole, immersive technology has the potential to create a positive and enriching learning experience. It offers advantages such as increased motivation and engagement, while the lifelike settings and interactive features of the Metaverse enhance the learning process. However, it is essential to acknowledge the potential weaknesses. These include the need for adequate training and support, as well as the importance of providing detailed instructions and preparation to ensure students can effectively utilize the immersive tools. Additionally, managing students' behavior within the Metaverse can be a challenge. Moving forward, further studies could focus on the development of professional development opportunities for educators. This will enable them to integrate immersive technology into their teaching practices effectively. Furthermore, addressing the accessibility of immersive technology is essential to ensure that learners can benefit from its potential.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

P.L. designed the overall conference framework and conceptualized the research study. V.K. collected the survey data for analysis. All authors were involved in the analysis of the survey results, interpreted the results and drafted the manuscript. All authors read and approved the final manuscript.

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References

[1] B. Kye, N. Han, E. Kim, Y. Park, and S, Jo, "Educational applications of Metaverse: Possibilities and limitations," *Journal of Educational Evaluation for Health Professions*, vol. 18, no. 32, Dec. 2021.

[2] X. Zhang, Y. Chen, L. Hu, and Y. Wang, "The Metaverse in education: Definition, framework, features, potential applications, challenges, and future research topics," *Frontiers in Psychology*, vol. 13, 1016300, 2022.

[3] M. Pradana and H. P. Elisa, "Metaverse in education: A systematic literature review," *Cogent Social Sciences*, vol. 9, no. 2, Sep. 2023.

[4] J. Jeon and S. K. Jung, "Exploring the educational applicability of Metaverse-based platforms," *Korea Association of Information Education*, vol. 8, pp. 361–368, Aug. 2021.

[5] C. Dede, "Immersive interfaces for engagement and learning," *Science*, vol. 323, no. 5910, pp. 66–69, 2009.

[6] J. Yuan, Y. Liu, X. Han, A. Li and L, Zhao, "Educational Metaverse: An exploration and practice of VR wisdom teaching model in Chinese open university English course," *Interactive Technology and Smart Education*, vol. 20, no. 3, pp. 403–421, 2023.

[7] B. Dalgarno and M. J. Lee, "What are the learning affordances of 3-D virtual environments?" *British Journal of Educational Technology*, vol. 41, no. 1, pp. 10–32, 2010.

[8] T. A. Mikropoulos and A. Natsis, "Educational virtual environments: A ten-year review of empirical research (1999–2009)," *Computers & Education*, vol. 56, no. 3, pp. 769–780, 2011.

[9] N. I. Gonzalez-Romo, G. Mignucci-Jiménez, S. Hanalioglu, M. E. Gurses, S. Bahadir, Y. Xu, G. Koskay, M. T. Lawton, and M. C. Preul, "Virtual neurosurgery anatomy laboratory: A collaborative and remote education experience in the Metaverse," *Surg Neurol Int*, vol. 14, no. 90, 2023.

[10] R. Cheng, E. Murat, L.-F. Yu, S. Chen, and B. Han, "Understanding online education in Metaverse: Systems and user experience perspectives," in *Proc. 2024 IEEE Conference Virtual Reality and 3D User Interfaces (VR)*, 2024, pp. 598–608.

[11] B. Dalgarno, J. Hedberg, and B. Harper, "The contribution of 3D environments to conceptual understanding," *Winds of Change in the Sea of Learning: Proceedings of the 19th Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education*, pp. 149–158, vol. 1, 2002.

[12] J. F. M. Falah, M. S. Khan, T. Alfalah, S. F. Alfalah, W. Chan, D. K. Harrison, and V. Charissis, "Virtual reality medical training system for anatomy education," in *Proc. 2014 Science and Information Conference*, pp. 752–758, 2014.

[13] L. Tarouco, B. Gorziza, Y. Corrêa, É. M. H. Amaral, and T. Müller, "Virtual laboratory for teaching calculus: An immersive experience," in *Proc. 2013 IEEE Global Engineering Education Conference (EDUCON)*, 2013, pp. 774–781.

[14] S. T. Bulu, "Place presence, social presence, co-presence, and satisfaction in virtual worlds," *Computers & Education*, vol. 58, no. 1, pp. 154–161, 2012.
[15] K. Yue, "Breaking down the barrier between teachers and students by using Metaverse technology in education: based on a survey and analysis of Shenzhen city, China," *IC4E '22: Proceedings of the 2022 13th International Conference on E-Education, E-Business, E-Management, and E-Learning*, pp. 40–44, 2022.
[16] P. Hodgson, V. W. Y. Lee, J. C. S. Chan, A. Fong, C. S. Y. Tang, L. Chan, and C. Wong, "Immersive Virtual Reality (IVR) in higher education: Development and implementation," in *Augmented Reality and Virtual Reality*, M. Claudia tom Dieck and T. Jung, Eds. Springer, 2019, pp. 161–173.
[17] B. Poolsawas and N. Chotikakamthorn, "Using mozilla hubs for online teaching: A case study of an innovation design method course," in *Proc. the 17th International Multi-Conference on Society, Cybernetics and Informatics*, eds. N. Callaos, J. Horne, B. Sánchez, and M. Savoie, pp. 7–12, 2023.
[18] A. Ariza-Montes, W. Quan, A. Radic, J. Yu and H. Han, "Human values and traveler behaviors: Metaverse for conferences and meetings," *Journal of Travel & Tourism Marketing*, vol. 40, no. 6, pp. 490–511, 2023.
[19] T. Eriksson, "Failure and success in using mozilla hubs for online teaching in a movie production course," in *Proc. 2021 7th International Conference of the Immersive Learning Research Network (iLRN)*, pp. 1–8, 2021.
[20] A. Yoshimura and C. W. Borst, "Evaluation and comparison of desktop viewing and headset viewing of remote lectures in VR with mozilla hubs," presented at International Conference on Artificial Reality and Telexistence, and Eurographics Symposium on Virtual Environments, 2020.
[21] M. Dunleavy, C. Dede, and R. Mitchell, "Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning," *Journal of Science Education and Technology*, vol. 18, no. 1, pp. 7–22, 2009.
[22] M. Alizadeh and N. Cowie, "An exploratory student-centred approach to immersive virtual reality: reflections and future directions," in *Back to the Future – ASCILITE '21. Proceedings ASCILITE 2021 in Armidale*, eds. S. Gregory, S. Warburton, and M. Schier, pp. 131–136, 2021.
[23] Y. Wang, L. H. Lee, T. Braud, and P. Hui, "Re-shaping post-COVID-19 teaching and learning: A blueprint of virtual-physical blended classrooms in the Metaverse era," in *Proc. 2022 IEEE 42nd International Conference on Distributed Computing Systems Workshops (ICDCSW)*, pp. 231–247, 2022.
[24] D. Allcoat and A. Mühlenen, "Learning in virtual reality: Effects on performance, emotion and engagement," *Research in Learning Technology*, vol. 26, no. 2140, 2018.
[25] L. Jarmon, "Pedagogy and learning in the virtual world of second life," in *Encyclopedia of Distance Learning, Second Edition*, P. L. Rogers, G. A. Berg, J. V. Boettcher, C. Howard, L. Justice, and K. D. Schenk, Eds. IGI Global, 2009, pp. 1610–1620.
[26] E. A. L. Lee, K. W. Wong, and C. C. Fung, "How does desktop virtual reality enhance learning outcomes? A structural equation modeling approach," *Computers & Education*, vol. 55, no. 4, pp. 1424–1442, 2010.
[27] A. Tlili, R. Huang, B. Shehata *et al*., "Is Metaverse in education a blessing or a curse: A combined content and bibliometric analysis," *Smart Learning Environments*, vol. 9, no. 24, 2022.
[28] M. M. Inceoglu and B. Ciloglugil, "Use of Metaverse in education," in *Computational Science and Its Applications – ICCSA 2022 Workshops, Lecture Notes in Computer Science*, O. Gervasi, B. Murgante, S. Misra, A. M. A. C. Rocha, and C. Garau, Eds. Springer, 2022, pp. 171–184.