Bridging Theory into Practice: An Investigation of the Opportunities and Challenges to the Implementation of Metaverse-Based Teaching in Higher Education Institutions

Abhishek Sharma[1](✉), Lakshmi Sharma[2], and Joanna Krezel[3]

[1] Institute of Health and Management, Melbourne, Australia
sharmaabhishek570@gmail.com
[2] Amity University, Noida, India
lakshmisharma9891@gmail.com
[3] Victoria University, Melbourne, Australia
joanna.krezel@vu.edu.au

Abstract. Due to the recent COVID-19 pandemic, there has been a shift in how education is delivered from face-to-face environments to virtual learning platforms. Moreover, virtual learning platforms are becoming increasingly popular in higher education institutions as they provide immersive experiences that improve student experience. Nevertheless, there are concerns about the large-scale implications of Metaverse-based learning systems within higher education institutions. With the increasing opportunities and challenges associated with Metaverse-based learning systems, this scoping review investigates the key opportunities and challenges associated with implementing Metaverse-based teaching in higher education institutions. In doing so, the study also showcases how theoretical notions of the technology acceptance model (i.e., TAM) and unified theory of acceptance and use of technology (i.e., UTAUT) are linked with user acceptance towards Metaverse-based teaching in higher education institutions. Additionally, keyword searches are carried out on Scopus, ProQuest, and Web of Science databases to screen out studies that meet the selection criteria of the analysis. In doing so, the study's findings are depicted with the help of VOSviewer, which showcases the key clusters and studies related to opportunities and challenges of Metaverse-based teaching in higher education institutions. The findings showcase that most of the studies are published on Metaverse and its related technologies, such as AR, and how it creates an immersive learning experience through the help of gamification. Finally, the paper concludes with future directions related to the large-scale implementation of Metaverse-based teaching in higher education institutions.

Keywords: Metaverse · Virtual Worlds · Virtual Learning Platforms · Higher Education Institutions · Technology Acceptance Model (TAM) · Unified Theory of Acceptance and Use of Technology (UTAUT)

P. Zaphiris and A. Ioannou (Eds.): HCII 2024, LNCS 14724, pp. 173–189, 2024.
https://doi.org/10.1007/978-3-031-61691-4_12

1 Introduction

With the gradual advancements in technology, there has been an increase in the way individuals use technologies such as Augmented Reality (i.e., AR)/Virtual Reality (i.e., VR)/Extended Reality (i.e., XR)/Mixed Reality (i.e., MR) and Metaverse (See Fig. 1) (Duan et al., 2021; Mystakidis, 2022). Moreover, studies also contend that Metaverse is one of the most debated topics as it provides immersive experiences for its users and allows them to interact within the virtual worlds. However, Metaverse and its wide range of implementations in various fields remain a contentious issue in existing literature (Rojas et al., 2023; Zhang et al., 2022). In general, Metaverse is a shared virtual space where individuals can interact in real-time with other users via digital avatars (De Felice et al., 2023; Mystakidis, 2022). From a technological viewpoint, Metaverse is a 3D virtual space that combines both technologies, such as AR (i.e., augmented reality) and VR (i.e., virtual reality) (De Felice et al., 2023; Gao et al., 2023). Several platforms, including Second Life, Sandbox, and Decentraland, allow users access to the Metaverse systems, where they can create realistic avatars that can attend conferences and concerts and interact with other users (De Felice et al., 2023; Trunfio & Rossi, 2022). Moreover, Metaverse provides the opportunity for users to interact via immersive internet platforms where users are not only seen to have higher levels of engagement but also are seen to have practical learning experiences (Beck et al., 2023; Onu et al., 2023; Sin et al., 2023; Suh et al., 2023; Villalonga-Gómez et al., 2023). Currently, Metaverse continues to gain popularity, with reports indicating that the user base for Metaverse systems is expected to reach approximately 5 billion by around 2030 (Morris, 2022; Sharma et al., 2023).

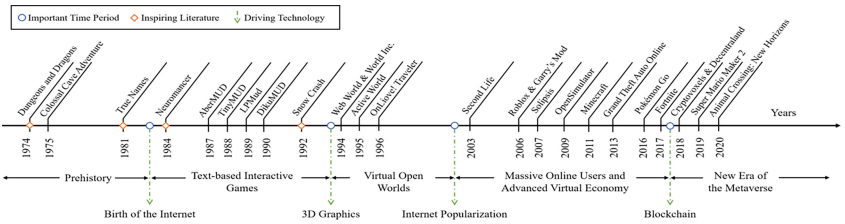

Fig. 1. Timeline for Gradual Advancements in Technology Source-(Duan et al., 2021)

In particular, Metaverse has gained immense attention of academics and researchers on how it can be implemented within the domains of entertainment (Chakraborty et al., 2023; Evans et al., 2022a; Niu & Feng, 2022; Sahoo et al. 2023), healthcare systems (Kim et al., 2023; Musamih et al., 2022; Petrigna & Musumeci, 2022; Tan et al., 2022; G. Wang et al., 2022), education (Kye et al., 2021; Mystakidis, 2022; Sharma et al., 2023; Tlili et al., 2022; Zhang et al., 2022), banking (Mozumder et al., 2023; Ooi et al., 2023; Sahoo & Ray, 2023; Zainurin et al., 2023), manufacturing (Z. Lin et al., 2022; Mourtzis et al., 2023a; Yao et al., 2022), advertising (Dwivedi et al., 2022; Eyada, 2023; Kim, 2021; Ozkaynar, 2023; Park & Kim, 2023), tourism (Buhalis et al., 2023; Koo et al., 2023; Tsai, 2022; Yang & Wang, 2023), retail (CHA, 2022; Gadalla et al., 2013; Hudson, 2022; Jenkins, 2022; Popescu et al., 2022), gaming (Evans et al., 2022b; Oliveira & Cruz,

2023; Onu et al., 2023) and real estate (Aharon et al., 2022; Kennedy, 2023; Yoo, 2022). The majority of these studies have either shed light on the varying opinions regarding the possibility of employing Metaverse in various sectors or on the determinants that will allow for Metaverse's adoption in a wide range of technological settings (Alfaisal et al., 2022; Dwivedi et al., 2022; Gao et al., 2023; Wu & Hao, 2023).

Within higher education institutions, Metaverse-based learning systems are mostly centred towards the development of captivating virtual environments that allow students to have higher knowledge retention (Akour et al., 2022; Lee & Kim, 2022; Rojas et al., 2023). Moreover, these studies also highlight various frameworks that would enable the implementation of Metaverse-based teaching in higher education institutions. However, only a few studies have unearthed the linkages of theoretical underpinnings of user acceptance towards the Metaverse platforms. Hence, the purpose of this study remains to (a) investigate the existing literature and related theories (i.e., Technology Acceptance Model, Unified Theory of Acceptance and Use of Technology) to understand the user acceptance towards Metaverse-based learning systems; (b) identify the key opportunities and challenges that are associated with the implementation of Metaverse-based teaching in higher education institutions.

To meet the objectives mentioned above of this study, a keyword search is conducted across three major databases, including Scopus, ProQuest, and Web of Science, to identify studies that elucidate theoretical notions as well as the key opportunities and challenges associated with the implementation of Metaverse-based teaching in higher education institutions. Additionally, to understand the trends within Metaverse-based teaching in higher education institutions, a co-occurrence analysis of keywords is conducted with the help of VOSviewer. The size of the labels within the figure denotes the number of occurrences of keywords within the extracted papers gathered from the Scopus database.

2 Background of the Study

Metaverse is an immersive platform that has the potential to reshape how education is delivered in HEIs by offering immersive experiences and enabling students to explore digital reality across various educational disciplines (Lin et al., 2022) (See Fig. 2). In detail, some of the positive impacts of Metaverse within higher education include (a) providing an immersive learning experience for students (Beck et al., 2023; Hwang et al., 2023; Sharma et al., 2023; Sin et al., 2023; Wei & Yuan, 2023); (b) Enhancing the visual experience for students (Di Natale et al., 2024; Han et al., 2022; Ng et al., 2023); (c) Creating hands-off experience for students which are of low-risk but of higher learning experience (Gómez-Cambronero et al., 2023; H. Lin et al., 2022; Sihna et al., 2023); (d) Personalised experiences (De Felice et al., 2023; Salloum et al., 2023; Sharma et al., 2023); (d) Fostering game based learning environments (Ng et al., 2023; Sihna et al., 2023); (e) collaborative experiences for development of new knowledge (Joshi & Pramod, 2023; Mourtzis et al., 2023b; Sharma et al., 2023).

Metaverse is in its infancy, and its potential is yet to be discovered in this technological age. However, it is vital to understand the prospective developments that existed as the building blocks of the Metaverse systems. To begin with, Second Life has been a

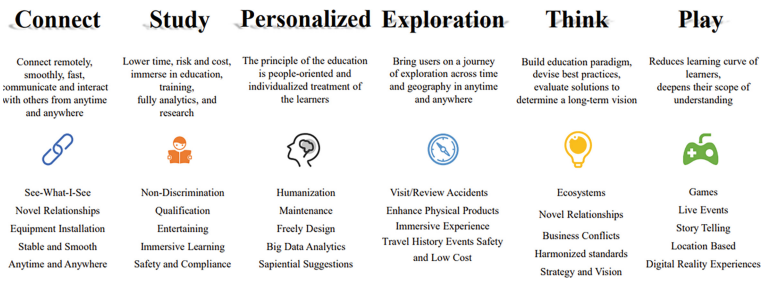

Fig. 2. Applications of Metaverse in Higher Education Institutions Source-(H. Lin et al., 2022)

driving force behind the Metaverse revolution, which was released in 2003 as a platform for multiplayer online gaming in virtual worlds through avatars (Onu et al., 2023). Following that, technological applications such as Unity, Roblox, Unreal Engine, Nvidia Omniverse, Hololens 2, and Oculus Quest 2 have been recognised as practical tools for implementing Metaverse systems (See Fig. 3).

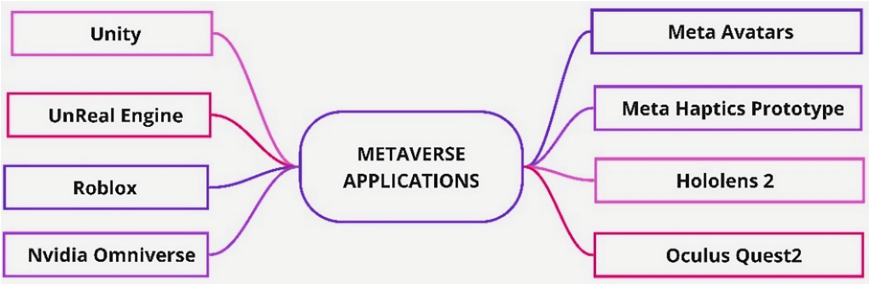

Fig. 3. Applications Related to Metaverse Systems Source- (Onu et al., 2023; Xu et al., 2022)

3 Theoretical Linkages in the Implementation of Metaverse-Based Teaching in Higher Education Institutions

3.1 Technology Acceptance Model (TAM)

With the rapid advancements in technology, it is crucial to understand the user acceptance towards a particular technology. From a theoretical standpoint, the technology acceptance model (i.e., TAM) is one of the critical frameworks that uncover the acceptance level of human behaviour, explaining the potential approval or disapproval of technology. In detail, TAM predicts the acceptance level of a user by understanding the perceived usefulness, perceived ease of use and attitude towards the use of technology. Moreover, TAM is also one of the prominent theories widely applied to various technologies ranging from mobile learning technologies to Metaverse technologies. The majority of studies conducted on the acceptance of a particular technology can be visualised to be taken by

learners, educators, and stakeholders (Al-Adwan & Al-Debei, 2023; Al-Adwan et al., 2023; Alkhwaldi, 2023). As a result, it is essential to understand how Metaverse-based teaching in higher education institutions might be accepted by students and educators in the current technological age. Hence, Table 1 showcases the studies that are relevant to the technology acceptance model (TAM) and the adoption of Metaverse-based learning systems in higher education institutions as follows: -

Table 1. Studies Pertaining to TAM & Metaverse-Based Learning Systems

Relevant Studies	Type of Study	Findings
Al-Adwan et al. (2023)	**Quantitative Study**	According to the study's findings, perceived usefulness, personal innovativeness in IT, and perceived enjoyment are essential enablers of students' behavioural intentions towards adopting metaverse-based learning systems in higher education institutions
İbili et al. (2023)	**Quantitative Study**	The study's findings show that students' behavioural intentions towards adopting metaverse-based learning systems in higher education institutions are significantly influenced by perceived usefulness and hedonic motivation
Salloum et al. (2023)	**Quantitative Study**	According to the study's findings, innovativeness's moderating impact is crucial as it contributes to users' pervasive perceptions of adopting metaverse-based learning systems in higher education institutions
Alkhwaldi (2023)	**Quantitative Study**	The study's findings show that user satisfaction, performance expectancy, facilitating conditions, and hedonic gratification all have a significant impact on students' behavioural intentions towards adopting metaverse-based learning systems in higher education institutions
Al-Adwan & Al-Debei (2023)	**Quantitative Study**	According to the study's findings, apart from social influence, all other included determinants (e.g., personnel innovativeness) significantly and positively impact students' adoption intentions for the metaverse in higher education learning environments

(*continued*)

Table 1. (*continued*)

Relevant Studies	Type of Study	Findings
Akour et al. (2022)	**Quantitative Study**	The study's findings show that students' perceptions of trialability, compatibility, observability, and complexity are positively associated with adopting metaverse-based learning systems in higher education institutions
Wang & Shin (2022)	**Quantitative Study**	The study's findings show that personalised learning, perceived ease of use, social needs, and social impact play a positive influence on the willingness to adopt Metaverse education systems

3.2 Unified Theory of Acceptance and Use of Technology (UTAUT)

In addition to TAM, UTAUT remains a key theory that provides a robust framework that explains the key factors behind a user's behaviour and their acceptance level of a particular technology. According to the UTAUT, the four independent factors contributing to user's behaviour and acceptance level are performance expectation, expected effort, social impact, and facilitating conditions (Lee & Kim, 2022). In light of these discussions, Venkatesh et al. (2012) also proposed the UTAUT2 model, which includes additional factors such as hedonic motivation, price value, and habit that would provide a deeper understanding towards the acceptance level of users towards a particular technology. Moreover, most studies have adopted the theoretical lenses of the UTAUT model to explain Metaverse-based teaching in higher education institutions. As a result, it is essential to understand how metaverse-based teaching in higher education institutions might be accepted by students and educators in the current technological age. Hence, studies relevant to the Unified Theory of Acceptance and Use of Technology (UTAUT) and the adoption of Metaverse-based teaching in higher education institutions are showcased in Table 2.

4 Methodology

Based on the data extracted from the Scopus database, metaverse-based learning systems have gained enormous attention in countries such as South Korea, China, and India due to their current technological revolution (See Fig. 4).

Also, the database results showcase that Metaverse-based learning systems have been implemented effectively in various educational fields, including computer science, social sciences, and engineering-related fields in higher education institutions (See Fig. 5).

Table 2. Studies Pertaining to UTAUT & Metaverse-Based Learning Systems

Relevant Studies	Type of Study	Findings
Kalınkara & Özdemir (2023)	**Quantitative Study**	According to the study's findings, social influence, habit variables, and facilitating conditions affect the behavioural intentions of students to adopt metaverse-based learning systems in higher education institutions. Furthermore, the study discovered that students had an elevated level of participation in hedonic motivation
Alkhwaldi (2023)	**Quantitative Study**	The study's findings revealed that an individual's behavioural intentions regarding the usage of Metaverse-based learning systems are influenced by their satisfaction, performance expectancy, and facilitating conditions
Wiangkham & Vongvit (2023)	**Quantitative Study**	The study's findings revealed that cyber security, performance expectancy, social influence, and hedonic motivation all significantly affect the intention to use metaverse-based learning systems in higher education institutions
Lee & Kim (2022)	**Quantitative Study**	Based on the study's findings, it was determined that students' satisfaction levels and intentions to use metaverse-based learning technologies are increased when they have higher expectations regarding their performance, their level of effort, and the social influence of these technologies

Besides this, to address the critical purpose of this study, a rigorous approach is taken, where a keyword search is conducted on various designated databases such as Scopus, ProQuest, and the Web of Science platforms to showcase the key opportunities and challenges that are associated with the implementation of Metaverse-based learning systems in higher education institutions (See Table 3). VOSviewer is implemented to analyse the cluster analysis of Metaverse and its implementation in higher education institutions based on the search results gathered from the Scopus database.

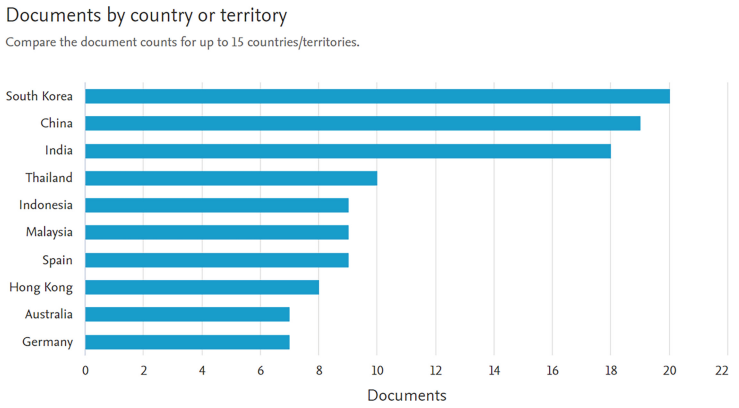

Fig. 4. Studies on Metaverse Learning Systems Published by Different Countries Source-(Scopus)

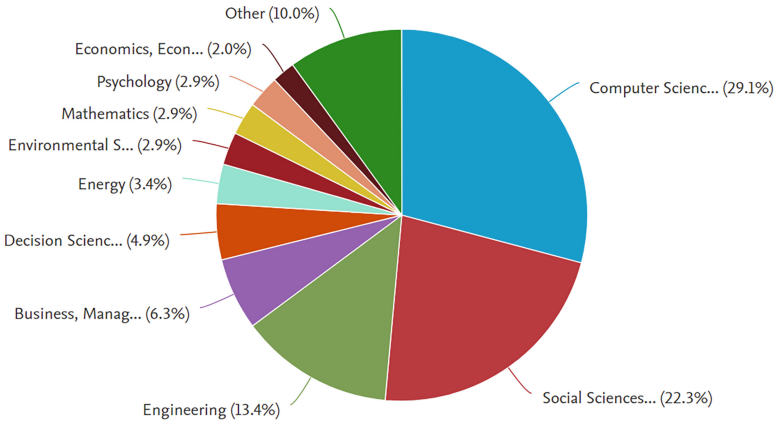

Fig. 5. Application of Metaverse Learning Systems in Various Fields of Higher Education Institutions Source-(Scopus)

More precisely, the co-occurrence analysis is undertaken in VOSviewer, which explores that there exist three major clusters (i.e., Red, Green, and Blue) that provide ideas on the implementation of Metaverse-based teaching in higher education institutions (See Fig. 6). Firstly, the red cluster signifies the concepts such as Metaverse and its related technologies, such as AR and how it creates immersive learning experiences through the help of gamification. Secondly, the blue clusters showcase the notions and studies linked to virtual reality, e-learning and higher education. Finally, the green clusters depict the studies related to virtual worlds, avatars, and extended reality.

Table 3. Keyword and Search Results from Designated Databases

Keywords	ProQuest	Scopus	Web of Science
(“Metaverse”) AND (“Opportunities” OR “Barriers”) AND (“Higher Education”) AND (“Teaching”)	219	–	–
(“Metaverse”) AND (“Opportunities” OR “Barriers”) AND (“Higher Education”) AND (“Teaching”) AND PUBYEAR > 2019 AND PUBYEAR < 2025 AND (LIMIT-TO (LANGUAGE, “English”)) AND (LIMIT-TO (EXACTKEYWORD, “Metaverse”))	–	156	–
(“Metaverse”) AND (“Opportunities” OR “Barriers”) AND (“Higher Education”) AND (“Teaching”)	–	–	2

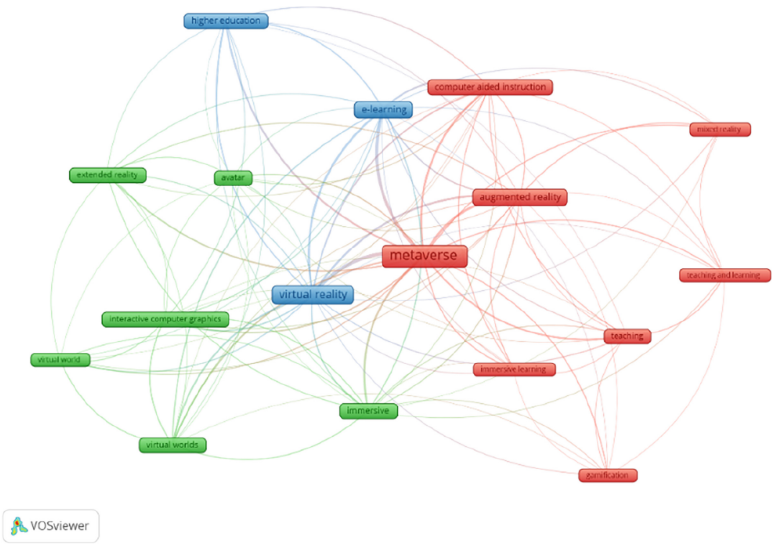

Fig. 6. Co-occurrence Analysis Through Vosviewer Source-(VOSviewer)

5 Key Opportunities and Challenges of Metaverse Technologies

With the growing popularity of Metaverse-based learning systems, it is critical to identify the opportunities and challenges associated with the implementation of Metaverse systems in higher education institutions (See Table 4 and Table 5). In detail, the key benefits of Metaverse systems in higher education institutions can be summarised as their ability to provide students with immersive and interactive experiences (Park & Kim, 2023; Richter & Richter, 2023; Said, 2023). Furthermore, some studies also state that metaverse-based learning systems not only provide personalised learning experiences for students but also provide students with an opportunity to learn skills through a

game-based approach to learning (Akour et al., 2022; Al-Adwan et al., 2023). Furthermore, Metaverse-based learning systems are thought to provide collaborative learning experiences for students, fostering a constructivist approach to learning among them (Kryvenko & Chalyy, 2023; Onu et al., 2023). Lastly, it is also assumed that the implementation of Metaverse-based learning systems will boost the digital literacy level of both students and teachers, allowing them to have an enhanced experience while using Metaverse systems (Farias-Gaytan et al., 2023; Simbaqueba-Uribe et al., 2024).

Table 4. Key Opportunities of Metaverse Systems

Key Opportunities of Metaverse Systems	Related Studies
Immersive & Interactive Learning Experience	AbuKhousa et al. (2023); Akour et al. (2022); Al-Adwan et al. (2023); Asiksoy (2023); Beck et al. (2023); Camilleri (2023); De Felice et al. (2023); George-Reyes et al. (2023); Hwang et al. (2023); JosephNg et al. (2023); Kaur et al. (2023); Li & Yu (2023); Maheswari et al. (2022); Mourtzis et al. (2023b); Onu et al. (2023); Park & Kim (2022); Richter & Richter (2023); Said (2023); Samarnggoon et al. (2023); Sin et al. (2023); Siyaev & Jo (2021); Villalonga-Gómez et al. (2023); Wei & Yuan (2023); Yilmaz et al. (2023)
Personalised Learning Experiences/Skill-Practising Environment/Game-Based Learning	AbuKhousa et al. (2023); Arantes (2023); George-Reyes et al. (2023); Kryvenko & Chalyy (2023); Mourtzis et al. (2023b); Onu et al. (2023); Samarnggoon et al. (2023)
Collaborative & Social Learning Experiences	De Felice et al. (2023); George-Reyes et al. (2023); Onu et al. (2023); Said (2023); Sharma et al. (2023); Sin et al. (2023); Tlili et al. (2022)
Constructivist Learning	Camacho & Esteve, (2015); Ng et al. (2023); Onu et al. (2023); Sin et al. (2023); Suh & Ahn (2022)
Digital Literacy	Farias-Gaytan et al. (2023); George-Reyes et al. (2023); Guzzo et al. (2023); Li & Yu (2023); Mohsin et al. (2023); Simbaqueba-Uribe et al. (2024); Sin et al. (2023); Villalonga-Gómez et al. (2023)

Table 5. Key Challenges of Metaverse Systems

Critical Challenges in Implementation of Metaverse Systems	Related Studies
Technical Limitations	De Felice et al. (2023); Mosco (2023); Onu et al. (2023); Yaqoob et al. (2023)
Privacy Breaches & Security Concerns/Cybersecurity Concerns	Al-Ghaili et al. (2022); Onu et al. (2023); Park & Kim (2022); Said (2023)
Health Concerns	Benrimoh et al. (2022); Song & Qin (2022); Wylde et al. (2023)
Ensuring Strong Governance on Metaverse Systems and User Behaviour	Mosco (2023); Ølnes et al. (2017); Said (2023); Wylde et al. (2023); Yaqoob et al. (2023)
Lack of Interconnectedness Among Various Metaverse Platforms	Al-Ghaili et al. (2022); Y. Wang et al. (2022); Zyda (2022)
Copyright & Intellectual Property Challenges	(Nanobashvili (2021); Ramos, (2022); Yaqoob et al. (2023)
Content Moderation Across Metaverse Platforms & Ethical Use of Avatar Integrity	Commission (2022); Hu et al. (2021); Lake (2019); Lau (2022); Lin & Latoschik (2022); Wylde et al. (2023)
Data Protection Frameworks	Lau (2022); Milmo (2023); Rahman (2022); Wylde et al. (2023)
Cost Associated with Metaverse Learning Systems Implementation	Koohang et al. (2023); Onu et al. (2023); Simbaqueba-Uribe et al. (2024); Zhang et al. (2023)
Lack of Resources for Content Creation in Metaverse Learning Systems	Onu et al. (2023); Velev et al. (2023); Zhang et al. (2023)
Addiction to Using Metaverse Systems	H. Lin et al. (2022); Mohammed et al. (2024); Pal & Arpnikanondt (2024); Yaqoob et al. (2023)

6 Conclusion and Future Research Directions

Following the COVID-19 pandemic, one of the most hotly debated topics is the Metaverse and its potential applications across various domains, including higher education. Furthermore, reflecting the arguments presented in the paper, it can be concluded that Metaverse not only provides an enhanced immersive experience for students but also comes with an array of challenges related to wide-scale implementations in higher education institutions. As a result, it is suggested that stakeholders, regulators, and government bodies need necessary actions to make substantial refinements in terms of privacy and governance of Metaverse systems.

References

AbuKhousa, E., El-Tahawy, M.S., Atif, Y.: Envisioning architecture of metaverse intensive learning experience (MiLEx): career readiness in the 21st century and collective intelligence development scenario. Future Internet **15**(2), 53 (2023)

Aharon, D.Y., Demir, E., Siev, S.: Real returns from unreal world? Market reaction to metaverse disclosures. Res. Int. Bus. Financ. **63**, 101778 (2022)

Akour, I.A., Al-Maroof, R.S., Alfaisal, R., Salloum, S.A.: A conceptual framework for determining metaverse adoption in higher institutions of gulf area: an empirical study using hybrid SEM-ANN approach. Comput. Educ.: Artif. Intell. **3**, 100052 (2022)

Al-Adwan, A.S., Al-Debei, M.M.: The determinants of Gen Z's metaverse adoption decisions in higher education: Integrating UTAUT2 with personal innovativeness in IT. Educ. Inf. Technol. 1–33 (2023)

Al-Adwan, A.S., Li, N., Al-Adwan, A., Abbasi, G.A., Albelbisi, N.A., Habibi, A.: Extending the technology acceptance model (TAM) to Predict University Students' intentions to use metaverse-based learning platforms. Educ. Inf. Technol. **28**(11), 15381–15413 (2023)

Al-Ghaili, A.M., et al.: A Review of Metaverse's Definitions, Architecture, Applications, Challenges, Issues, Solutions, and Future Trends. IEEE Access (2022)

Alfaisal, R., Hashim, H., Azizan, U.H.: Metaverse system adoption in education: a systematic literature review. J. Comput. Educ. 1–45 (2022)

Alkhwaldi, A.F.: Understanding learners' intention toward Metaverse in higher education institutions from a developing country perspective: UTAUT and ISS integrated model. Kybernetes (2023)

Arantes, J.: Digital twins and the terminology of "personalization" or "personalized learning" in educational policy: a discussion paper. Policy Futures Educ. 14782103231176357 (2023)

Asiksoy, G.: Empirical studies on the metaverse-based education: a systematic review. Int. J. Eng. Pedagogy **13**(3), 120–133 (2023)

Beck, D., Morgado, L., O'Shea, P.: Educational practices and strategies with immersive learning environments: mapping of reviews for using the metaverse. IEEE Trans. Learn. Technol. (2023)

Benrimoh, D., Chheda, F.D., Margolese, H.C.: The best predictor of the future—the metaverse, mental health, and lessons learned from current technologies. JMIR Mental Health **9**(10), e40410 (2022)

Buhalis, D., Leung, D., Lin, M.: Metaverse as a disruptive technology revolutionising tourism management and marketing. Tour. Manage. **97**, 104724 (2023)

Camacho, M., Esteve, V.: Moving beyond learning: the potential of inmmersive environmesnts in education. Teach. Learn. Digit. World: Strateg. Issues High. Educ. **70**, 109 (2015)

Camilleri, M.A.: Metaverse applications in education: a systematic review and a cost-benefit analysis. Interact. Technol. Smart Educ. (2023)

Cha, S.-S.: Metaverse and the evolution of food and retail industry. Korean J. Food Health Converg. **8**(2), 1–6 (2022)

Chakraborty, D., Patre, S., Tiwari, D.: Metaverse mingle: discovering dating intentions in metaverse. J. Retail. Consum. Serv. **75**, 103509 (2023)

Commission, E.: Shaping Europe's digital future: a European strategy for a better internet for kids (2022). https://digital-strategy.ec.europa.eu/en/policies/strategy-better-internet-kids

De Felice, F., Petrillo, A., Iovine, G., Salzano, C., Baffo, I.: How does the metaverse shape education? A systematic literature review. Appl. Sci. **13**(9), 5682 (2023)

Di Natale, A.F., Repetto, C., Costantini, G., Riva, G., Bricolo, E., Villani, D.: Learning in the metaverse: are university students willing to learn in immersive virtual reality? Cyberpsychol. Behav. Soc. Netw. **27**(1), 28–36 (2024)

Duan, H., Li, J., Fan, S., Lin, Z., Wu, X., Cai, W.: Metaverse for social good: a university campus prototype. In: Proceedings of the 29th ACM International Conference on Multimedia (2021)
Dwivedi, Y.K., et al.: Metaverse beyond the hype: multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. Int. J. Inf. Manage. **66**, 102542 (2022)
Evans, L., Frith, J., Saker, M.: Entertainment worlds. In: From Microverse to Metaverse, pp. 65–73. Emerald Publishing Limited (2022a)
Evans, L., Frith, J., Saker, M.: Gaming worlds. In: From Microverse to Metaverse: Modelling the Future through Today's Virtual Worlds, pp. 33–40. Emerald Publishing Limited (2022b)
Eyada, B.: Advertising in the metaverse: opportunities and challenges. Int. J. Market. Stud. **15**(1) (2023)
Farias-Gaytan, S., Aguaded, I., Ramirez-Montoya, M.-S.: Digital transformation and digital literacy in the context of complexity within higher education institutions: a systematic literature review. Human. Soc. Sci. Commun. **10**(1), 1–11 (2023)
Gadalla, E., Keeling, K., Abosag, I.: Metaverse-retail service quality: a future framework for retail service quality in the 3D internet. J. Mark. Manag. **29**(13–14), 1493–1517 (2013)
Gao, H., Chong, A.Y.L., Bao, H.: Metaverse: literature review, synthesis and future research agenda. J. Comput. Inf. Syst. 1–21 (2023)
George-Reyes, C.E., Peláez Sánchez, I.C., Glasserman-Morales, L.D., López-Caudana, E.O.: The Metaverse and complex thinking: opportunities, experiences, and future lines of research. Front. Educ. (2023)
Gómez-Cambronero, Á., Miralles, I., Tonda, A., Remolar, I.: Immersive virtual-reality system for aircraft maintenance education: a case study. Appl. Sci. **13**(8), 5043 (2023)
Guzzo, T., Ferri, F., Grifoni, P.: Lessons learned during COVID-19 and future perspectives for emerging technology. Sustainability **15**(14), 10747 (2023)
Han, D.-I.D., Bergs, Y., Moorhouse, N.: Virtual reality consumer experience escapes: preparing for the metaverse. Virtual Reality **26**(4), 1443–1458 (2022)
Hu, J., Iosifescu, A., LiKamWa, R.: Lenscap: split-process framework for fine-grained visual privacy control for augmented reality apps. In: Proceedings of the 19th Annual International Conference on Mobile Systems, Applications, and Services (2021)
Hudson, J.: Virtual immersive shopping experiences in metaverse environments: predictive customer analytics, data visualization algorithms, and smart retailing technologies. Linguist. Philos. Investigat. **21**, 236–251 (2022)
Hwang, Y., Shin, D., Lee, H.: Students' perception on immersive learning through 2D and 3D metaverse platforms. Educ. Technol. Res. Developm. 71(4), 1687–1708 (2023)
İbili, E., et al.: Investigation of learners' behavioral intentions to use metaverse learning environment in higher education: a virtual computer laboratory. Interact. Learn.. Environ. 1–26 (2023)
Jenkins, T.: Immersive virtual shopping experiences in the retail metaverse: consumer-driven E-commerce, blockchain-based digital assets, and data visualization tools. Linguist. Philos. Investigat. **21**, 154–169 (2022)
JosephNg, P.S., Gong, X., Singh, N., Sam, T.H., Liu, H., Phan, K.Y.: Beyond your sight using metaverse immersive vision with technology behaviour model. J. Cases Inf. Technol. **25**(1), 1–34 (2023)
Joshi, S., Pramod, P.: A collaborative metaverse based a-la-carte framework for tertiary education (CO-MATE). Heliyon **9**(2), e13424 (2023)
Kalınkara, Y., Özdemir, O.: Anatomy in the metaverse: exploring student technology acceptance through the UTAUT2 model. Anatom. Sci. Educ. (2023)
Kaur, N., Singh, V., Mahajan, N., Garg, N.: Game based learning-immersive teaching and learning platform through metaverse. In: 2023 3rd International Conference on Innovative Practices in Technology and Management (ICIPTM) (2023)

Kennedy, J.: Metaverse property: advocating for the regulation of metaverse land and property through a real estate legal regime. Ohio St. Bus. LJ **17**, 323 (2023)
Kim, J.: Advertising in the metaverse: research agenda. J. Interact. Advert. **21**(3), 141–144 (2021)
Kim, K., Yang, H., Lee, J., Lee, W.G.: Metaverse wearables for immersive digital healthcare: a review. Adv. Sci. **10**(31), 2303234 (2023)
Koo, C., Kwon, J., Chung, N., Kim, J.: Metaverse tourism: conceptual framework and research propositions. Curr. Issue Tour. **26**(20), 3268–3274 (2023)
Koohang, A., et al.: Shaping the metaverse into reality: a holistic multidisciplinary understanding of opportunities, challenges, and avenues for future investigation. J. Comput. Inf. Syst. **63**(3), 735–765 (2023)
Kryvenko, I., Chalyy, K.: Phenomenological toolkit of the metaverse for medical informatics' adaptive learning. Educ. Méd. **24**(5), 100854 (2023)
Kye, B., Han, N., Kim, E., Park, Y., Jo, S.: Educational applications of metaverse: possibilities and limitations. J. Educ. Eval. Health Profess. **18**, 32 (2021)
Lake, J.: Hey, you stole my avatar!: virtual reality and its risks to identity protection. Emory LJ **69**, 833 (2019)
Lau, P.L.: The metaverse: three legal issues we need to address (2022). https://theconversation.com/the-metaverse-three-legal-issues-we-need-to-address-175891
Lee, U.-K., Kim, H.: UTAUT in Metaverse: an "Ifland" case. J. Theor. Appl. Electron. Commer. Res. **17**(2), 613–635 (2022)
Li, M., Yu, Z.: A systematic review on the metaverse-based blended English learning. Front. Psychol. **13**, 1087508 (2023)
Lin, H., Wan, S., Gan, W., Chen, J., Chao, H.-C.: Metaverse in education: vision, opportunities, and challenges. In: 2022 IEEE International Conference on Big Data (Big Data) (2022)
Lin, J., Latoschik, M.E.: Digital body, identity and privacy in social virtual reality: a systematic review. Front. Virtual Reality **3**, 974652 (2022)
Lin, Z., Xiangli, P., Li, Z., Liang, F., Li, A.: Towards metaverse manufacturing: a blockchain-based trusted collaborative governance system. In: The 2022 4th International Conference on Blockchain Technology (2022)
Maheswari, D., Ndruru, F.B.F., Rejeki, D.S., Moniaga, J.V., Jabar, B.A.: Systematic literature review on the usage of iot in the metaverse to support the education system. In: 2022 5th International Conference on Information and Communications Technology (ICOIACT) (2022)
Milmo, D.: Meta dealt blow by EU ruling that could result in data use 'opt-in' (2023). https://www.theguardian.com/technology/2023/jan/04/meta-dealt-blow-eu-ruling-data-opt-in-facebook-instagram-ads
Mohammed, S.Y., Aljanabi, M., Gadekallu, T.R.: Navigating the nexus: a systematic review of the symbiotic relationship between the metaverse and gaming. Int. J. Cognit. Comput. Eng. **5**, 88–103 (2024)
Mohsin, A.N., Mohammed, M.A., Al-Maatoq, M.: Employing metaverse technologies to improve the quality of the educational process. In: International Multi-disciplinary Conference-Integrated Sciences and Technologies (2023)
Morris, C.: Citi says metaverse economy could be worth $13 trillion by 2030. Fortune (2022). https://fortune.com/2022/04/01/citi-metaverse-economy-13-trillion-2030/
Mosco, V.: Into the metaverse: technical challenges, social problems, utopian visions, and policy principles. Javnost-The Public **30**(1), 161–173 (2023)
Mourtzis, D., Angelopoulos, J., Panopoulos, N.: Blockchain integration in the era of industrial metaverse. Appl. Sci. **13**(3), 1353 (2023)
Mourtzis, D., Angelopoulos, J., Panopoulos, N.: Metaverse and blockchain in education for collaborative product-service system (PSS) design towards University 5.0. Procedia CIRP **119**, 456–461 (2023)

Mozumder, M.A.I., Theodore, A.T.P., Athar, A., Kim, H.-C.: The metaverse applications for the finance industry, its challenges, and an approach for the metaverse finance industry. In: 2023 25th International Conference on Advanced Communication Technology (ICACT) (2023)
Musamih, A., et al.: Metaverse in healthcare: applications, challenges, and future directions. IEEE Consum. Electron. Magaz. (2022)
Mystakidis, S.: Metaverse. Encyclopedia **2**(1), 486–497 (2022)
Nanobashvili, L.: If the metaverse is built, will copyright challenges come? UIC Rev. Intell. Prop. L. **21**, i (2021)
Ng, P.H., et al.: From classroom to metaverse: a study on gamified constructivist teaching in higher education. Int. Conf. Web-Based Learn. (2023)
Niu, X., Feng, W.: Immersive entertainment environments-from theme parks to metaverse. Int. Conf. Hum.-Comput. Interact. (2022)
Oliveira, A., Cruz, M.: Virtually connected in a multiverse of madness?—perceptions of gaming, animation, and metaverse. Appl. Sci. **13**(15), 8573 (2023)
Ølnes, S., Ubacht, J., Janssen, M.: Blockchain in Government: Benefits and Implications of Distributed Ledger Technology for Information Sharing, vol. 34, pp. 355–364. Elsevier (2017)
Onu, P., Pradhan, A., Mbohwa, C.: Potential to use metaverse for future teaching and learning. Educ. Inf. Technol. 1–32 (2023)
Ooi, K.-B., et al.: Banking in the metaverse: a new frontier for financial institutions. Int. J. Bank Market. **41**(7), 1829–1846 (2023)
Ozkaynar, K.: Consumer behavior, marketing approach, branding, advertising, and new opportunities in the metaverse areas. In: Metaverse: Technologies, Opportunities and Threats, pp. 151–159. Springer (2023)
Pal, D., Arpnikanondt, C.: The sweet escape to metaverse: exploring escapism, anxiety, and virtual place attachment. Comput. Hum. Behav. **150**, 107998 (2024)
Park, J., Kim, N.: Examining self-congruence between user and avatar in purchasing behavior from the metaverse to the real world. J. Glob. Fashion Market. 1–16 (2023)
Park, S.-M., Kim, Y.-G.: A metaverse: taxonomy, components, applications, and open challenges. IEEE Access **10**, 4209–4251 (2022)
Petrigna, L., Musumeci, G.: The metaverse: a new challenge for the healthcare system: a scoping review. J. Funct. Morphol. Kinesiol. **7**(3), 63 (2022)
Popescu, G.H., Valaskova, K., Horak, J.: Augmented reality shopping experiences, retail business analytics, and machine vision algorithms in the virtual economy of the metaverse. J. Self-Gov. Manag. Econ. **10**(2), 67–81 (2022)
Rahman, M.: The Metaverse – What Does It Mean for Data Privacy and Information Security? (2022). https://www.jdsupra.com/legalnews/the-metaverse-what-does-it-mean-for-2751284/
Ramos, A.: The metaverse, NFTs and IP rights: to regulate or not to regulate? Intellectual property forum. J. Intellect. Indust. Property Soc. Australia New Zealand (2022)
Richter, S., Richter, A.: What is novel about the metaverse? Int. J. Inf. Manage. **73**, 102684 (2023)
Rojas, E., Hülsmann, X., Estriegana, R., Rückert, F., Garcia-Esteban, S.: Students' perception of metaverses for online learning in higher education: hype or hope? Electronics **12**(8), 1867 (2023)
Sahoo, D., Ray, S.: Metaverse in banking: an initiative for banking transformation from emerging country prospective. Acad. Market. Stud. J. **27**(S4) (2023)
Sahoo, N., Gupta, D., Sen, K.: Metaverse: the pursuit to keep the human element intact in the media and entertainment industry. In: The Business of the Metaverse, pp. 156–167. Productivity Press (2023)
Said, G.R.E.: Metaverse-based learning opportunities and challenges: a phenomenological metaverse human-computer interaction study. Electronics **12**(6), 1379 (2023)
Salloum, S., et al.: Sustainability model for the continuous intention to use metaverse technology in higher education: a case study from Oman. Sustainability **15**(6), 5257 (2023)

Samarnggoon, K., Grudpan, S., Wongta, N., Klaynak, K.: Developing a virtual world for an open-house event: a metaverse approach. Future Internet **15**(4), 124 (2023)
Sharma, A., Sharma, L., Krezel, J.: Exploring the use of metaverse for collaborative learning in higher education: a scoping review. Int. Conf. Hum.-Comput. Interact. (2023)
Sihna, A., Raj, H., Das, R., Bandyopadhyay, A., Swain, S., Chakrborty, S.: Medical education system based on metaverse platform: a game theoretic approach. In: 2023 4th International Conference on Intelligent Engineering and Management (ICIEM) (2023)
Simbaqueba-Uribe, J., Alvarez-Risco, A., Del-Aguila-Arcentales, S., Rojas-Osorio, M., Mejia, C.R., Yañez, J.A.: Training courses by metaverse: intention of consumers in Colombia. Developm. Stud. Res. **11**(1), 2292474 (2024)
Sin, Z.P., et al.: Towards an edu-metaverse of knowledge: immersive exploration of university courses. IEEE Trans. Learn. Technol. (2023)
Siyaev, A., Jo, G.-S.: Towards aircraft maintenance metaverse using speech interactions with virtual objects in mixed reality. Sensors **21**(6), 2066 (2021)
Song, Y.-T., Qin, J.: Metaverse and personal healthcare. Procedia Comput. Sci. **210**, 189–197 (2022)
Suh, I., McKinney, T., Siu, K.-C.: Current Perspective of Metaverse Application in Medical Education, Research and Patient Care. Virtual Worlds (2023)
Suh, W., Ahn, S.: Utilizing the metaverse for learner-centered constructivist education in the post-pandemic era: an analysis of elementary school students. J. Intelligence **10**(1), 17 (2022)
Tan, T.F., et al.: Metaverse and virtual health care in ophthalmology: opportunities and challenges. Asia-Pacific J. Ophthalmol. **11**(3), 237–246 (2022)
Tlili, A., et al.: Is metaverse in education a blessing or a curse: a combined content and bibliometric analysis. Smart Learn. Environ. **9**(1), 1–31 (2022)
Trunfio, M., Rossi, S.: Advances in metaverse investigation: streams of research and future agenda. Virtual Worlds **1**(2), 103–129 (2022)
Tsai, S.-P.: Investigating metaverse marketing for travel and tourism. J. Vacat. Market. 13567667221145715 (2022)
Velev, D., Dimitrov, D., Zlateva, P.: Challenges of metaverse in education digitalization. In: Digitalization and Management Innovation II, pp. 43–51. IOS Press (2023)
Venkatesh, V., Thong, J.Y., Xu, X.: Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology. MIS Quart. **36**(1), 157–178 (2012)
Villalonga-Gómez, C., Ortega-Fernández, E., Borau-Boira, E.: Fifteen years of metaverse in higher education: a systematic literature review. IEEE Trans. Learn. Technol. **16**(6), 1057–1070 (2023)
Wang, G., et al.: Development of metaverse for intelligent healthcare. Nat. Mach. Intell. **4**(11), 922–929 (2022)
Wang, G., Shin, C.: Influencing factors of usage intention of metaverse education application platform: empirical evidence based on PPM and TAM models. Sustainability **14**(24), 17037 (2022)
Wang, Y., et al.: A survey on metaverse: fundamentals, security, and privacy. IEEE Commun. Surv. Tutor. (2022)
Wei, Z., Yuan, M.: Research on the current situation and future development trend of immersive virtual reality in the field of education. Sustainability **15**(9), 7531 (2023)
Wiangkham, A., Vongvit, R.: Exploring the Drivers for the Adoption of Metaverse Technology in Engineering Education using PLS-SEM and ANFIS. Educ. Inf. Technol. 1–28 (2023)
Wu, T., Hao, F.: Edu-metaverse: concept, architecture, and applications. Interact. Learn. Environ. 1–28 (2023)
Wylde, V., Prakash, E., Hewage, C., Platts, J.: Post-covid-19 metaverse cybersecurity and data privacy: present and future challenges. In: Data Protection in a Post-Pandemic Society: Laws, Regulations, Best Practices and Recent Solutions, pp. 1–48. Springer (2023)

Xu, M., et al.: A full dive into realizing the edge-enabled metaverse: visions, enabling technologies, and challenges. IEEE Commun. Surv. Tutor. **25**(1), 656–700 (2022)
Yang, F.X., Wang, Y.: Rethinking metaverse tourism: a taxonomy and an agenda for future research. J. Hosp. Tourism Res. 10963480231163509 (2023)
Yao, X., Ma, N., Zhang, J., Wang, K., Yang, E., Faccio, M.: Enhancing wisdom manufacturing as industrial metaverse for industry and society 5.0. J. Intell. Manuf. 1–21 (2022)
Yaqoob, I., Salah, K., Jayaraman, R., Omar, M.: Metaverse applications in smart cities: enabling technologies, opportunities, challenges, and future directions. Internet Things **23**, 100884 (2023)
Yilmaz, M., O'farrell, E., Clarke, P.: Examining the training and education potential of the metaverse: results from an empirical study of next generation SAFe training. J. Softw. Evolut. Process e2531 (2023)
Yoo, J.: A study on transaction service of virtual real estate based on metaverse. J. Inst. Internet Broadcast. Commun. **22**(2), 83–88 (2022)
Zainurin, M.Z.L., Haji Masri, M., Besar, M.H.A., Anshari, M.: Towards an understanding of metaverse banking: a conceptual paper. J. Financ. Report. Account. **21**(1), 178–190 (2023)
Zhang, K., Shao, Z., Lu, Y., Yu, Y., Sun, W., Wang, Z.: Introducing massive open metaverse course (MOMC) and its enabling technology. IEEE Trans. Learn. Technol. **16**(6), 1154 (2023)
Zhang, X., Chen, Y., Hu, L., Wang, Y.: The metaverse in education: definition, framework, features, potential applications, challenges, and future research topics. Front. Psychol. **13**, 6063 (2022)
Zyda, M.: Let's rename everything "the metaverse!" Computer **55**(3), 124–129 (2022)