Contemporary Educational Technology, 2025, **17**(3), ep584
ISSN: 1309-517X (Online)

OPEN ACCESS

Review Article

Metaverse-based learning: A comprehensive review of current trends, challenges, and future implications

Thanapat Sripan [1]
0009-0006-2850-4384

Pattarawat Jeerapattanatorn [1*]
0009-0001-1858-867X

[1] Faculty of Education, Kasetsart University, Bangkok, THAILAND
[*] Corresponding author: pattarawat.j@ku.th

Citation: Sripan, T., & Jeerapattanatorn, P. (2025). Metaverse-based learning: A comprehensive review of current trends, challenges, and future implications. *Contemporary Educational Technology, 17*(3), ep584. https://doi.org/10.30935/cedtech/16434

ARTICLE INFO

Received: 3 Mar 2025

Accepted: 22 May 2025

ABSTRACT

Based on an analysis of 36 peer-reviewed publications from academic databases, including ERIC, Scopus, Web of Science, and Google Scholar, this review article provides an in-depth examination of the current trends, challenges, and future implications of metaverse-based learning in education. To ascertain the quality and applicability of the papers studied, the scoping review applied a thorough methodology that included specific inclusion and exclusion criteria. A thematic analysis approach was employed to extract and synthesize the collected data. To guarantee the consistency and dependability of the results, tools like quality evaluation frameworks and structured data extraction forms were used. Findings revealed that immersive technologies like virtual reality, augmented reality, gamification, and collaborative virtual environments represent key developments that have significantly enhanced student engagement, practical skill development, and individualized learning experiences. However, there are also obstacles including high cost, limited accessibility, teacher readiness, and data concerns about privacy that keep widespread use in resource-poor places. The results show how metaverse technologies have the potential to democratize access to academic excellence, transcend cultural and geographic barriers, and facilitate experiential learning through simulation-based systems. Future studies must deal with these issues by examining the long-term effects of artificial intelligence-powered adaptive learning systems and concentrating on inclusive design, affordable solutions, and the moral use of data. If these barriers are overcome, the metaverse might serve as an essential tool for improving fair, exciting, and cutting-edge education globally.

Keywords: metaverse-based learning, immersive learning, educational challenges, personalized education

INTRODUCTION

With its novel teaching and learning opportunities, the incorporation of metaverse technology into education has attracted a lot of interest lately. Immersion, interaction, and teamwork are made possible by the metaverse, a collective virtual shared space made possible by the combination of persistent virtual environments and virtually improved physical reality (Lin et al., 2022). Traditional educational paradigms are changing as a result of this digital evolution, opening the door to more accessible and engaging learning settings (Tlili et al., 2023). The development of virtual classrooms and campuses, which enable interaction between students and teachers in environments that mimic the real world, is one of the main uses of the metaverse in education (Zhou & Kim, 2022). Regardless of geographic limitations, this method enables both synchronous and asynchronous learning, allowing participants to participate in group projects, lectures, and conversations (Wang et al., 2022). Immersion experiences that promote learning through interaction and teamwork have also been developed using platforms such as Second Life and other virtual reality (VR) environments (Bailenson, 2022). Furthermore, through role-playing games and simulations, the metaverse facilitates experiential learning. In disciplines like medicine, engineering, and the sciences, it is especially advantageous for students to be able to practice skills in safe and regulated settings (Mirault et al., 2023). For instance, engineering students can test prototypes in the metaverse, and medical students can conduct virtual surgeries thanks to VR-based simulations, which offer practical experience without the expenses and dangers of in-person practice (Bazhenova et al., 2020).

Additionally, the metaverse encourages accessibility and inclusion in the classroom. Customized virtual environments that meet their needs can help students with impairments or those who encounter obstacles in traditional classroom settings, offering equal opportunity for engagement and education (Lombeyda et al., 2022). Furthermore, by providing underrepresented or underserved communities with resources and experiences, the metaverse democratizes access to high-quality education and closes educational gaps (Smith & Jones, 2023). Metaverse technology adoption in education is not without its difficulties, though. To guarantee successful implementation, concerns including digital literacy, data privacy, access to required technology, and the requirement for significant infrastructure and training investments must be addressed (Jagatheesaperumal et al., 2022). In order to successfully incorporate these technologies into curriculum and make sure they improve rather than detract from the learning process, educators must also create new pedagogical methodologies (Wang et al., 2022). In conclusion, the metaverse has the potential to revolutionize education by offering accessible, engaging, and immersive learning environments. In order to fully reap the benefits of metaverse applications, educational institutions must carefully integrate them while resolving related issues as technology advances (Lin et al., 2022). Navigating this new environment and utilizing its potential to improve teaching and learning outcomes will require constant research and cooperation between educators, technologists, and legislators (Tlili et al., 2023).

The goal of this paper is to present a thorough examination of metaverse-based learning (MBL), looking at both its present uses and its potential in educational settings in the future. This paper examines the main technological developments influencing the adoption of the metaverse, discusses the ethical and practical obstacles that institutions must overcome, and identifies possible directions for further study and policy creation by combining the results of 36 peer-reviewed publications. By doing this, this review aims to map the current state of metaverse-based learning and offer practical advice to academics, educators, and policymakers who want to use this game-changing technology to improve education. The following research questions (RQs) are the focus of this study:

RQ1: What are the key trends in the use of metaverse technology in education?

RQ2: What challenges must be overcome to implement metaverse-based learning?

RQ3: How do these results affect the formulation of future studies and policies?

These inquiries were created to support the overarching goal of combining various viewpoints from literature and offering practical suggestions to technology and education stakeholders.

METHOD

This study used a scoping review methodology, guided by the paradigm put forward by Arksey and O'Malley (2005) and further developed by Levac et al. (2010), to thoroughly examine and map the body of existing literature on metaverse-based learning. Without the requirement for a thorough critical evaluation of individual studies, this method was chosen to identify important themes, research gaps, and opportunities for further investigation. This methodology's adaptability makes it possible to incorporate a broad variety of evidence, which makes it especially appropriate for new and quickly developing domains like metaverse-based learning. The following steps made up the methodology.

Identifying Relevant Studies

Multiple academic databases, including ERIC, Scopus, Web of Science, and Google Scholar, were thoroughly searched to ensure coverage of both technological and pedagogical viewpoints. Keywords like "VR and AR learning," "metaverse in education," and "immersive technologies" were chosen with care to strike a balance between inclusivity and specificity. Wildcard symbols (*) and Boolean operators (AND and OR) were

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Focused on metaverse-based learning	Non-peer-reviewed articles
Published in English from 2022-2024	Not in educational contexts
Providing empirical or theoretical insights	Studies lacking substantive analysis

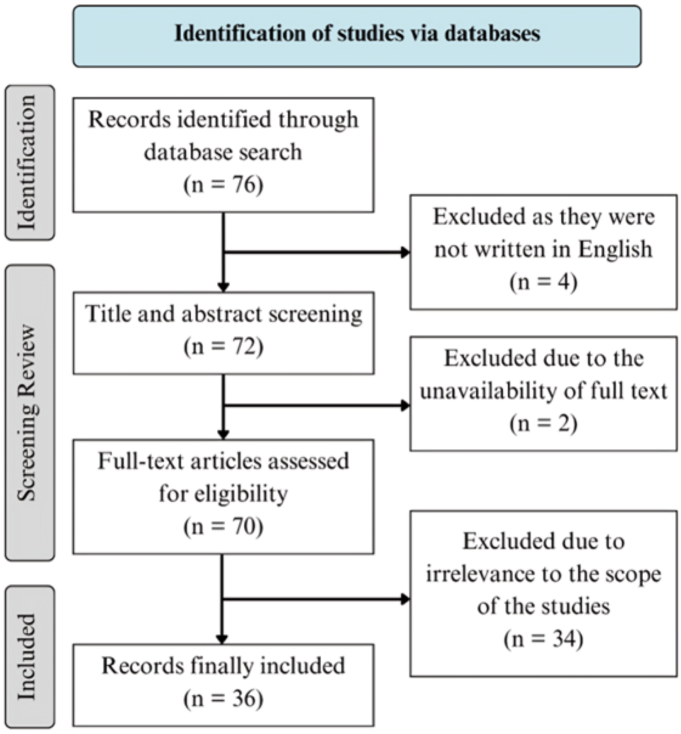

Figure 1. Screening process of the study (Source: Authors' own elaboration)

used to capture terminology variances and optimize search results. Additionally, to make sure no important studies—especially those from interdisciplinary domains—were missed, manual reference checks of a chosen number of papers were carried out.

Selecting Studies

The inclusion and exclusion criteria were strictly followed to preserve quality and relevance. To guarantee consistency with the research objectives, a full-text review was conducted after an initial screening of titles and abstracts (**Table 1**).

While the number of articles included (n = 36) may appear limited, the study applied strict inclusion criteria focusing on peer-reviewed publications from 2022–2024 to ensure relevance and recency. The use of four major databases (ERIC, Scopus, Web of Science, and Google Scholar) provided sufficient disciplinary breadth within a fast-evolving research domain (**Appendix A**).

Charting the Data

Using a standardized data extraction form, data extraction was carried out methodically, gathering important details such study goals, methods, sample attributes, technical focus (e.g., VR and augmented reality [AR]), and findings. Consistency was guaranteed by this methodical technique, which also made cross-study comparison easier. During the thematic synthesis process, the extracted data were arranged in an extensive table that was iteratively improved to include new information. Multiple reviewers cross-checked the extraction process to ensure correctness and clarity while reducing the possibility of mistakes or omissions. In addition to supporting strong synthesis, this systematic data arrangement offered a clear framework for evaluating intricate findings from various sources. The screening process for the study, shown in **Figure 1**, began with 76 records obtained from database searches. A total of 36 records were considered for analysis after language, full-text availability, and relevance-based exclusion criteria were applied.

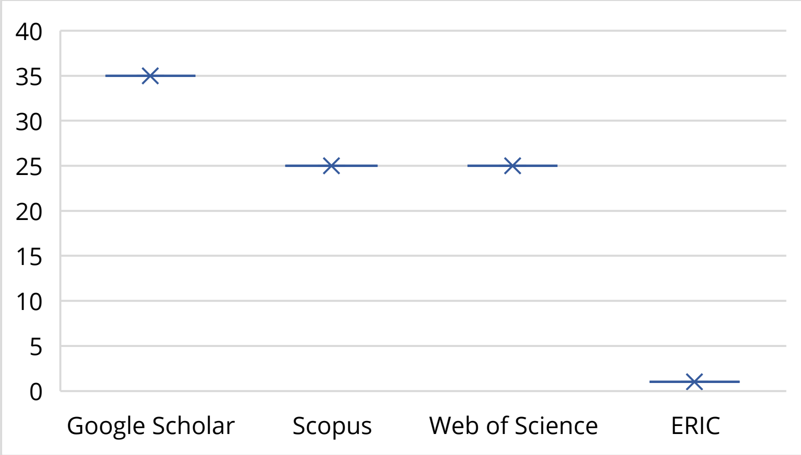

Figure 2. Number of articles by databases (Source: Authors' own elaboration)

Collating, Summarizing, and Reporting Results

Finding recurrent themes, gaps, and links in the literature was accomplished by thematic analysis, which combined findings from several studies. Results are given narratively with visual summaries, such as tables and figures, to improve clarity. For researchers, educators, and policymakers, these visual aids make findings more actionable by highlighting trends and relationships. This methodical and open approach charts the terrain of metaverse-based education, providing insightful information on patterns and a strong basis for further study and applications in the area.

RESULTS

Since it has the potential to completely transform teaching and learning methods, the incorporation of the metaverse into education has attracted a lot of attention recently. This review summarizes the results of 36 peer-reviewed studies that look at the various uses, difficulties, and possibilities of metaverse technology in the classroom. As a reflection of the increasing interest in this revolutionary digital environment, the research includes a wide range of fields, including STEM education, healthcare training, collaborative learning, and teacher preparedness. Providing a thorough overview of the use of the metaverse in educational settings and identifying trends, gaps, and future research paths are the main goals of this paper.

Data extraction form provides a summary of the research' target areas, methodology, and main conclusions to aid in a structured examination. Insights into the trends of metaverse-based learning today and its consequences for academics, educators, and policymakers are the goal of this synopsis. This review's succinct summary of the body of research provides a starting point for delving into important issues like the viability, accessibility, and effectiveness of metaverse technology in educational context. Future conversations on the metaverse's capacity to rethink educational paradigms and tackle enduring issues in the field will be informed by the findings.

Figure 2 demonstrates the number of articles retrieved from four databases: Google Scholar, Scopus, Web of Science, and ERIC. Google Scholar has the highest count (35), while ERIC has the lowest (1). The count includes duplicates.

The study's article distribution by affiliated nations and geographic areas is shown in **Figure 3** and **Figure 4**. With six papers, South Korea leads the field, followed by the USA with five and Japan with four, according to **Figure 3**, which shows the number of articles by affiliated nations. Other nations that produced less pieces included India, the United Arab Emirates, and a few others.

A geographical distribution map of the chosen studies is shown in **Figure 4**, which shows that most contributions originated in North America, East Asia, and parts of Europe. This finding reflects the interest in metaverse-based learning around the world, but it also suggests that research efforts are concentrated in technologically advanced countries.

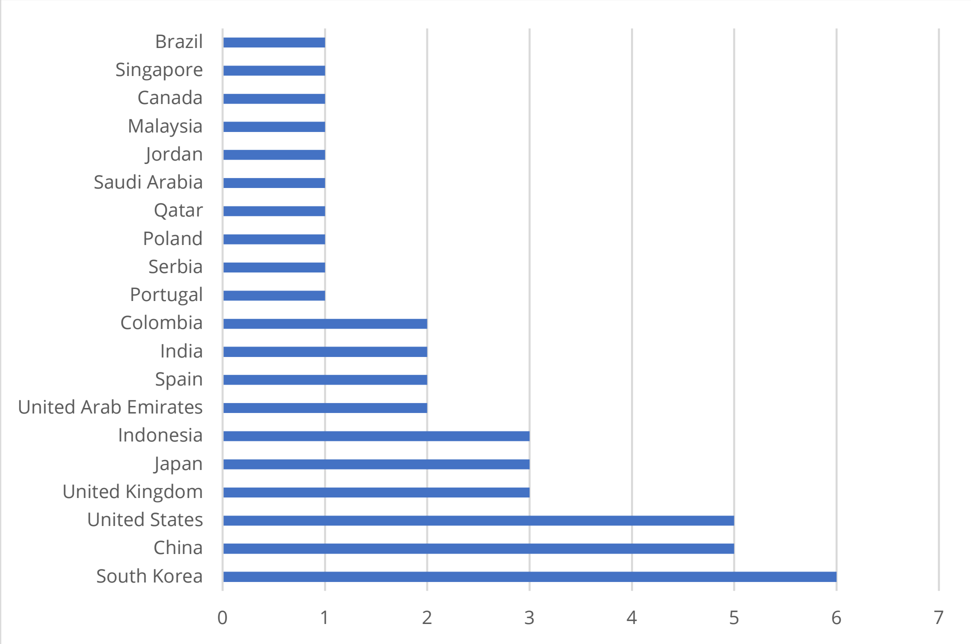

Figure 3. Number of articles by affiliated countries (Source: Authors' own elaboration)

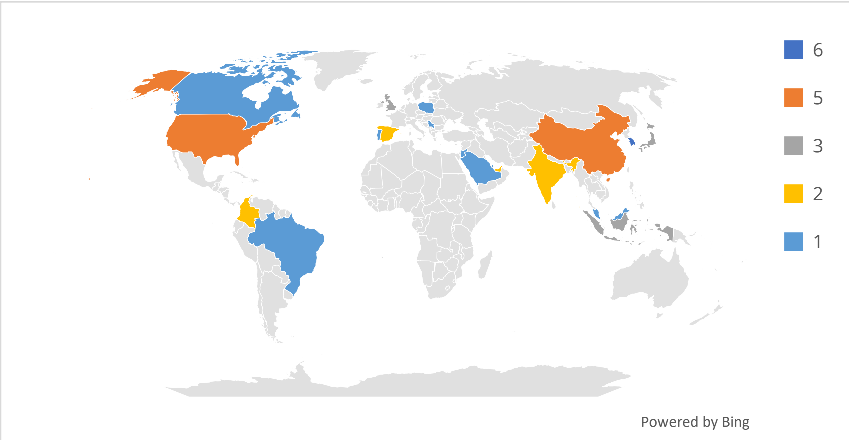

Figure 4. Geographical distribution of selected studies (Source: Authors' own elaboration)

Based on the frequency of keywords used in the chosen research, **Figure 5** shows that "metaverse" is the most frequently used phrase, followed by "virtual reality," "education," and "learning." "artificial intelligence (AI)" and "augmented reality (AR)," two keywords associated with upcoming technologies, also show up a lot, suggesting a strong emphasis on integrating technology into educational settings. Among the less often used terms are "privacy," "sustainability," and "performance," indicating that these topics need more research.

Current Trends in Metaverse-Based Learning

Based on the synthesis of the reviewed research articles using the data extraction form and the thematic analysis approach, the current trends in metaverse-based learning are presented in **Table 2**.

The current metaverse-based learning trends found in the studies analyzed are shown in **Table 2**. According to the research, medical education hybrid learning makes use of metaverse technologies to improve interactive anatomy and medical simulations, offering a risk-free setting for skill development. By making difficult topics more approachable, gamified experiences—like escape rooms and maze-based activities—have been demonstrated to dramatically increase student engagement and learning outcomes in STEM education. Real-time gamified components are skillfully incorporated into collaborative learning platforms such as VoRtex, encouraging student participation and teamwork. Additionally, by facilitating more participatory and self-directed learning experiences, the use of flipped and e-learning methodologies in

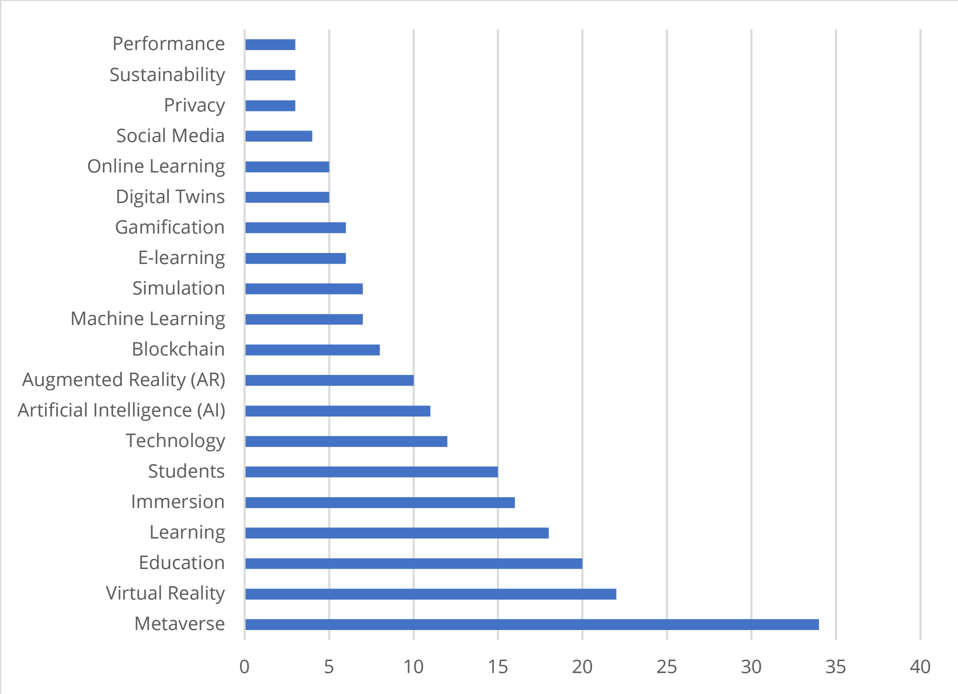

Figure 5. Frequencies of keywords of selected studies (Source: Authors' own elaboration)

Table 2. Current trends in metaverse-based learning

Trends	Description	Supporting articles
Hybrid learning in medical education	The use of metaverse to enhance interactive anatomy and medical simulations	Almarzouqi et al. (2022), Ullah et al. (2023)
Gamified experiences for sustainable learning	Leveraging escape room and maze-based activities to improve STEM education	Han et al. (2023), Jovanović and Milosavljević (2022), Park and Kim (2022), Rahman et al. (2024)
Collaborative learning platforms	Platforms like VoRtex integrate real-time gamified learning and collaboration	Jovanović and Milosavljević (2022), Muthmainnah et al. (2023), Zen and Hidayat (2022)
Flipped and e-learning readiness	Blending flipped classroom techniques with metaverse tools to improve critical thinking	López-Belmonte et al. (2022), Srisawat and Piriyasurawong (2022)
Integration of AR/VR for practical training	AR and VR technologies enhance hands-on learning experiences	Lee and Hwang (2022), Rahman et al. (2024), Zen and Hidayat (2022)

conjunction with metaverse technologies promotes the growth of critical thinking abilities. By offering realistic simulations that let students practice skills in real-world training scenarios without the constraints of physical resources, the combination of AR and VR technologies also significantly improves hands-on learning. All of these developments point to the expanding potential of metaverse-based learning to revolutionize conventional teaching methods.

Challenges in Metaverse-Based Learning

The challenges of metaverse-based learning remain intriguing and have garnered significant attention from educators. These challenges are presented in **Table 3**.

The main issues with metaverse-based learning that were found in the analyzed research are shown in **Table 3**. The results show that the digital divide and a lack of infrastructure are obstacles that prevent the egalitarian adoption of metaverse technologies, especially in areas with poor access to reasonably priced and dependable internet. Risks to privacy and security, such as possible data breaches and illegal access to private data in online settings, are highlighted as important issues that could erode consumer confidence. Significant technical obstacles arise from the intricacy of incorporating AR/VR technology into hands-on learning, necessitating a large investment and level of experience that many institutions lack.

Table 3. Challenges in metaverse-based learning

Challenges	Description	Supporting articles
Digital divide and infrastructure	Limited access to affordable and reliable internet in many regions	Firdaus (2023), Indarta et al. (2022), Zen and Hidayat (2022)
Privacy and security issues	Risks of data breaches in virtual environments	Almarzouqi et al. (2022), Hambali et al. (2023), Indarta et al. (2022), Kaddoura and Al Husseiny (2023), Ullah et al. (2023)
Technological barriers in mixed reality	Complexity of AR/VR integration for practical learning	Jovanović and Milosavljević (2022), Lee and Hwang (2022), Zen and Hidayat (2022)
Aligning user expectations with features	Misalignment of metaverse features with user needs leads to dissatisfaction	Almarzouqi et al. (2022), Srisawat and Piriyasurawong (2022)
Teacher training in VR-making	Teachers need training to effectively create and implement VR content	Lee and Hwang (2022), Rahman et al. (2024)

Table 4. Future implications in metaverse-based learning

Future implications	Description	Supporting articles
Cost-effective AR/VR in education	Democratizing access to high-quality medical training through affordable VR solutions	Almarzouqi et al. (2022), Firdaus (2023), Ullah et al. (2023)
Expanding gamified learning frameworks	Using gamification techniques to enhance learning across various disciplines	Park and Kim (2022), Rahman et al. (2024), Srisawat and Piriyasurawong (2022)
Personalized learning environments	Intelligent tutoring systems offering tailored educational experiences	Jovanović and Milosavljević (2022), Lee and Hwang (2022), Lévy and Zapata-Ros (2023), Sisamud et al. (2023)
Scalable mixed reality solutions	Enhancing collaboration and interactivity in STEM education	Rahman et al. (2024), Zen and Hidayat (2022)
Integration of AR/VR in K-12 settings	Diverse teaching methods enhanced through AR/VR technologies for younger learners	Lee and Hwang (2022), Li and Yu (2023), López-Belmonte et al. (2022)

Furthermore, user discontent frequently results from a misalignment between metaverse features and user wants, highlighting the significance of creating settings that are more intuitive and user-centered. Effective use of these technologies is made more difficult by teachers' lack of training in developing and implementing VR content, which exposes a lack of resources for professional development. Together, these difficulties highlight the necessity of all-encompassing approaches to technical and infrastructure constraints, privacy, security, and human resource development in order to successfully integrate metaverse-based learning into the classroom.

Future Implications for Education

The results extracted on the future implications for education reveal several interesting aspects, as presented in **Table 4**.

The main future implications of metaverse-based learning that were found in the analyzed studies are shown in **Table 4**. According to the findings, cheap AR/VR systems have the potential to democratize access to high-quality medical education by lowering costs and increasing accessibility for institutions with limited funding. It has been demonstrated that using gamification approaches to expand gamified learning frameworks improves learning outcomes and student engagement in a variety of subject areas, particularly STEM education.

Furthermore, intelligent tutoring systems that support personalized learning environments can offer customized educational experiences that adjust to the needs of each learner, enhancing performance and retention. Scalable mixed reality solutions are praised for their capacity to improve interaction and teamwork while simplifying difficult ideas through practical applications. It has also been discovered that incorporating AR and VR technology into K-12 classrooms supports a variety of instructional pedagogies, encouraging younger pupils to learn via experience. With an emphasis on increased accessibility, engagement, and customized learning experiences, these implications collectively point to a potential path for the use of metaverse technology in education. In summary, key insights of metaverse-based learning are illustrated in **Figure 6**.

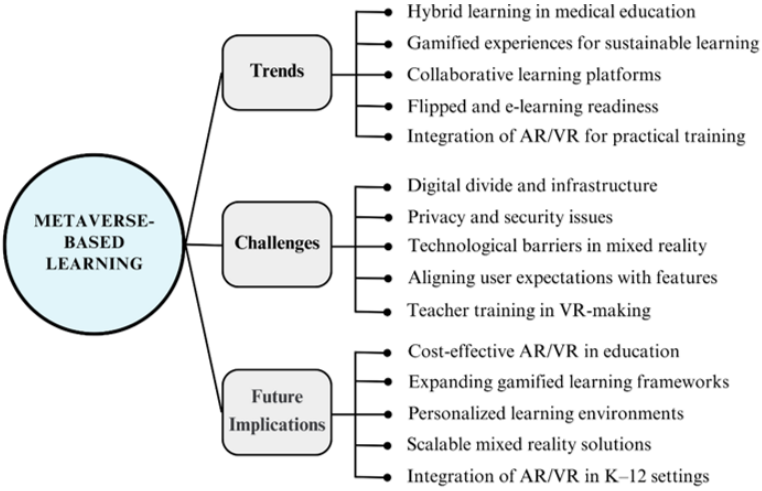

Figure 6. Key insight of metaverse-based learning (Source: Authors' own elaboration)

DISCUSSION

The main conclusions of the study are summarized in this section, which also provides an analysis of the trends, challenges, and potential future applications of metaverse technologies in education. The discussion addresses obstacles and identifies opportunities for further investigation while highlighting the metaverse's revolutionary potential by placing these findings within the body of previous scholarship.

Trends in Metaverse-Based Learning

The results show that major trends that alter conventional teaching and learning methodologies have been brought about by the incorporation of metaverse technology into education. Gamified experiences and hybrid learning models have become popular tactics, showcasing their ability to improve interaction and engagement in online settings. These patterns are consistent with earlier research, such as conducted by Tlili et al. (2023), which emphasizes how immersive and experiential learning in the metaverse can connect theoretical knowledge with real-world abilities. The emergence of customized learning environments made possible by intelligent systems is another noteworthy trend. These systems promote self-paced learning and enhance results by adjusting to the specific demands of each learner. In addition to improving accessibility for a variety of student populations, this personalization supports the inclusiveness and equity objectives of contemporary education (Zhou & Kim, 2022). Additionally, by bringing together students from various geographical locations, the metaverse promotes collaborative learning by allowing them to collaborate in real time on common projects in virtual settings. These exchanges foster cooperation and intercultural understanding, two qualities that are becoming more and more important in the connected world of today. Though these developments represent advancements, their widespread and successful application nevertheless necessitates strong pedagogical and infrastructure foundations.

Challenges in Implementing Metaverse Technologies

Although metaverse-based education has the potential to be transformative, there are significant obstacles to overcome. The digital gap is still a significant obstacle, especially in developing nations where there is limited access to dependable internet and cutting-edge technology. These differences highlight the necessity of distributing infrastructure and technology resources fairly (Lin et al., 2022). Furthermore, the results lead to a serious lack of readiness among instructors to successfully incorporate metaverse tools. This gap must be filled by professional development programs that give educators the pedagogical techniques and technical know-how they need to succeed (Lombeyda et al., 2022). Concerns about security and privacy also surfaced as significant problems, especially when it came to managing and collecting data in virtual settings. These results support Smith and Jones's (2023) worries over the moral ramifications of using the metaverse in the classroom. Additionally, many organizations find it difficult to afford the cost of deploying metaverse technologies. The cost might be prohibitive for everything from purchasing technology to creating personalized content. In order to provide affordable solutions and regulatory frameworks, legislators, technologists, and educators must work together to address these issues.

Future Implications for Education

As new technologies continue to develop and become integrated into educational settings, the future of education in the metaverse seems bright. Adaptive learning experiences that meet the needs of each individual student could be greatly enhanced by AI and machine learning. Particularly in professions that demand intricate problem-solving and practical experience, these technologies can further improve engagement and results (Tlili et al., 2023). Another important effect is scalability, which allows virtual classrooms to host bigger, more varied audiences. Students from marginalized communities can now access high-quality materials and experiences thanks to this development, which promotes international cooperation and the democratization of education (Lin et al., 2022; Sripan & Jeerapattanatorn, 2022). The results also indicate that inclusion and ethical considerations should be given top priority in future metaverse implementations. To reduce hazards such an excessive dependence on virtual surroundings or the possibility of social isolation, policymakers and educators must provide rules. These initiatives are in line with suggestions made by Smith and Jones (2023), who stress the significance of developing sustainable and responsible frameworks for the use of the metaverse in education. In conclusion, despite ongoing difficulties, the metaverse will have revolutionary effects on education in the future. Teachers and other stakeholders can fully utilize this technology to establish more equal, interesting, and productive learning environments by removing existing obstacles and utilizing new trends.

Limitations

Despite the value of this review, several limitations should be acknowledged. First, the review only included studies published between 2022 and 2024 to ensure timeliness and relevance. While this timeframe aligns with the rapid emergence of metaverse-based learning, it may have excluded earlier foundational work or grey literature. Second, although the study drew from four major databases (ERIC, Scopus, Web of Science, and Google Scholar), there is a possibility that relevant interdisciplinary studies indexed elsewhere were missed. Lastly, due to the nature of a scoping review, this study did not perform a quality assessment of the included studies, which limits the ability to draw conclusions about the strength of the evidence. Future reviews may expand both the temporal range and methodological scope to provide a more comprehensive synthesis.

CONCLUSION

Immersive, interactive, and inclusive learning environments are made possible by metaverse technology, which can be reshaped by this study. The highlighted trends highlight the metaverse's capacity to overcome the limitations of traditional education while also promoting participation, cooperation, and critical thinking. These trends include gamification, individualized education, and hybrid learning models. These innovations demonstrate a shift toward more dynamic and student-centered approaches, aligning with modern pedagogical goals. Nevertheless, there are substantial obstacles to deploying metaverse technologies that are highlighted by the results. Ensuring equitable and sustainable use of these tools requires addressing issues such as the digital divide, lack of teacher preparedness, privacy and security concerns, and the high cost of adoption. In addition, stakeholders must focus on the essential issue of aligning technical breakthroughs with instructional approaches. It will need a concerted effort by educators, legislators, and technologists to find affordable and scalable answers to these problems. With the metaverse as a foundation, educational opportunities for the future seem bright. New possibilities for inclusive, flexible, and scalable learning spaces are opening up thanks to emerging technologies like AI and ML. Incorporating these techniques can also improve learning analytics, which in turn helps teachers better tailor lessons to each student's unique needs and address those needs as they arise. Making sure that metaverse apps put students' needs first in terms of accessibility, fairness, and mental health will require careful ethical deliberation and solid frameworks. Overall, there are still some obstacles, but the metaverse might completely change the way people learn by making high-quality education more accessible and improving the quality of what students already have. In order to reach its maximum potential and establish a long-term educational environment for generations to come, research and cross-disciplinary cooperation are very necessary.

Recommendations

To improve the uptake and efficacy of metaverse-based learning, this review expands upon its conclusions and points out its limitations before offering numerous suggestions. A more sustainable, egalitarian, and impactful integration of metaverse technologies in education can be achieved by addressing practical implementation, policy development, and topics for future research.

Recommendations for practices

Several important strategies are suggested to make sure that metaverse-based learning is implemented effectively and inclusively. To begin, there must be a significant investment in digital infrastructure and accessibility. Governments and educational institutions must work together to expand access to the internet, lower the cost of virtual reality headsets, and assist low-income schools in closing the digital achievement gap. Institutions should provide workshops, certifications, and continuing assistance to assist educators in properly integrating AR/VR tools into their lessons. Comprehensive teacher training is also essential. In order to comply with legislation such as GDPR, it is crucial to establish strong privacy and security measures to safeguard user data. This will necessitate cooperation between institutions and developers of technology. Immersive and gamified learning experiences that are in line with learning objectives can be created through collaborative curriculum design, which involves educators, technologists, and instructional designers. Last but not least, reducing financial obstacles and increasing school access to metaverse technologies can be achieved through the adoption of scalable and cost-effective solutions, such as open-source platforms and partnerships with technology providers. In order to ensure the long-term viability of metaverse-based learning, these solutions work together to improve infrastructure, training, security, and cost-efficiency.

Recommendations for future research

Future study should focus on advancing the effective and ethical use of metaverse technology in education. Several important topics have been identified. To begin, longitudinal research spanning several stages of education would shed light on the most important questions concerning the effects of metaverse-based learning on students' ability to retain information, acquire new skills, and ultimately their academic success. Concerns like virtual reality weariness and an excessive dependence on virtual interactions, as well as their impact on social and communication abilities, should be the primary foci of future research into the social and psychological impacts of extended use of immersive environments. Supporting various learner groups, particularly those in underserved locations and with disabilities, requires prioritizing accessibility and inclusivity. Research should investigate adaptive features, such as configurable avatars and real-time transcription. Concerns about data privacy, content moderation, and algorithmic bias must be addressed through the creation of thorough ethical frameworks to guarantee the responsible use of metaverse technology. The potential of virtual labs and cross-field cooperation to improve education and spur creativity is another area that needs further investigation into interdisciplinary applications. Lastly, in order to assess the financial viability of implementing metaverse technologies, institutions need thorough cost-benefit studies. These analyses will aid in making informed decisions about the allocation of resources and long-term planning. Improved accessibility, efficacy, and sustainability of education based on the metaverse are the overarching goals of these research priorities.

Author contributions: TS: conceptualization, methodology, resources, data curation, writing – original draft, writing – review & editing; **PJ:** resources, data curation, formal analysis, writing – original draft, writing – review & editing. Both authors approved the final version of the article.

Funding: The authors received no financial support for the research and/or authorship of this article.

Ethics declaration: This study is a scoping review of existing published studies. As such, it does not involve any experiments on humans or animals, and ethical approval was not required. All sources used were publicly available and cited appropriately.

Declaration of interest: The authors declared no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

REFERENCES

Al-Adwan, A. S., Li, N., Al-Adwan, A., Abbasi, G. A., Albelbisi, N. A., & Habibi, A. (2023). Extending the technology acceptance model (TAM) to predict university students' intentions to use metaverse-based learning platforms. *Education and Information Technologies, 28*, 15381–15413. https://doi.org/10.1007/s10639-023-11816-3

Almarzouqi, A., Aburayya, A., & Salloum, S. A. (2022). Prediction of user's intention to use metaverse system in medical education: A hybrid SEM-ML learning approach. *IEEE Access, 10*, 43421–43432. https://doi.org/10.1109/ACCESS.2022.3169285

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology, 8*(1), 19–32. https://doi.org/10.1080/1364557032000119616

Asfarian, A., Nurhadryani, Y., Ardiansyah, F., Hermadi, I., & Ramadhan, D. A. (2022). From immersive to metaverse: The gap of learning and technology in agriculture education application. *Jurnal Ilmu Komputer dan Agri-Informatika, 9*(2), 127–136. https://doi.org/10.29244/jika.9.2.127-136

Bailenson, J. N. (2022). Nonverbal overload: A theoretical argument for the causes of Zoom fatigue. *Technology, Mind, and Behavior, 2*(1). https://doi.org/10.1037/tmb0000030

Bazhenova, E., Radianti, J., & Munkvold, B. E. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education*, *147*, Article 103778. https://doi.org/10.1016/j.compedu.2019.103778

Buckley, C., Holley, D., & Fallin, L. (2023). A manifesto for the metaverse: Opportunities and challenges for learning development. *Journal of Learning Development in Higher Education, Special Issue 29*. https://doi.org/10.47408/jldhe.vi29.1127

Cai, C. (2024). Research on the effectiveness of metaverse-based learning in business courses: A systematic review. *Journal of Education and Educational Research, 7*(2), 251–257. https://doi.org/10.54097/mnanpn41

Chamorro-Atalaya, O., Durán-Herrera, V., Suarez-Bazalar, R., Gonzáles-Pacheco, A., Quipuscoa-Silvestre, M., Hernández-Hernández, F., Huaman-Flores, E., Chaccara-Contreras, V., Palacios-Huaraca, C., & Guía-Altamirano, T. (2023). The metaverse in university education during COVID-19: A systematic review of success factors. *International Journal of Learning, Teaching and Educational Research, 22*(5), 206–226. https://doi.org/10.26803/ijlter.22.5.10

Chen, X., Zou, D., Xie, H., & Wang, F. L. (2023). Metaverse in education: Contributors, cooperations, and research themes. *IEEE Transactions on Learning Technologies, 16*(6), 1111–1129. https://doi.org/10.1109/TLT.2023.3277952

Dahan, N. A., Al-Razgan, M., Al-Laith, A., Alsoufi, M. A., Al-Asaly, M. S., & Alfakih, T. (2022). Metaverse framework: A case study on e-learning environment (ELEM). *Electronics, 11*(10), Article 1616. https://doi.org/10.3390/electronics11101616

De Felice, F., Petrillo, A., Iovine, G., Salzano, C., & Baffo, I. (2023). How does the metaverse shape education? A systematic literature review. *Applied Sciences, 13*(9), Article 5682. https://doi.org/10.3390/app13095682

Dong, H., & Lee, J. S. A. (2023). The metaverse from a multimedia communications perspective. *IEEE MultiMedia, 29*(4), 123–127. https://doi.org/10.1109/MMUL.2022.3217627

Firdaus, T. (2023). Representative platform cyber metaverse terkoneksi BYOD sebagai upaya preventive urgensi digital pada sistem pendidikan Indonesia [Representative platform cyber metaverse connected BYOD as a preventive effort to digital urgency in the Indonesian education system]. *Jurnal Integrasi dan Harmoni Inovatif Ilmu-Ilmu Sosial, 3*(2), 123–131. https://doi.org/10.17977/um063v3i2p123-131

Gonçalves, L., Martins, D., Oliveira, L., & Amaro, A. C. (2022). Amiais in Second Life™: The use of metaverse environments to disseminate cultural heritage. *Observatorio (OBS) Journal, 16*(3), 101–119. https://doi.org/10.15847/obsOBS16320222215

Hambali, Y. A., Putra, R. R. J., & Wahyudin, W. (2023). Implementasi metaverse menggunakan aplikasi Gather Town untuk pendidikan jarak jauh dengan pendekatan virtual learning environment [Implementation of metaverse using Gather Town application for distance education with virtual learning environment approach]. *Information System for Educators and Professionals, 7*(2), 163–172. https://doi.org/10.51211/isbi.v7i2.2039

Han, J., Liu, G., & Gao, Y. (2023). Learners in the metaverse: A systematic review on the use of Roblox in learning. *Education Sciences, 13*(3), Article 296. https://doi.org/10.3390/educsci13030296

Indarta, Y., Ambiyar, A. D. S., & Watrianthos, R. (2022). Metaverse: Tantangan dan peluang dalam Pendidikan [Metaverse: Tantangan dan peluang dalam pendidikan]. *Jurnal Basicedu, 6*(3), 3351–3363. https://doi.org/10.31004/basicedu.v6i3.2615

Jagatheesaperumal, S. K., Ahmad, K., Al-Fuqaha, A., & Qadir, J. (2022). Advancing education through extended reality and Internet of Everything enabled metaverses: Applications, challenges, and open issues. *IEEE Transactions on Learning Technologies, 17*, 1120–1139. https://doi.org/10.1109/TLT.2024.3358859

Jovanović, A., & Milosavljević, A. (2022). VoRtex metaverse platform for gamified collaborative learning. *Electronics, 11*(3), Article 317. https://doi.org/10.3390/electronics11030317

Kaddoura, S., & Al Husseiny, F. (2023). The rising trend of metaverse in education: Challenges, opportunities, and ethical considerations. *PeerJ Computer Science, 9*, Article e1252. https://doi.org/10.7717/peerj-cs.1252

Lee, H., & Hwang, Y. (2022). Technology-enhanced education through VR-making and metaverse-linking to foster teacher readiness and sustainable learning. *Sustainability, 14*(8), Article 4786. https://doi.org/10.3390/su14084786

Lee, J. (2022). A study on the intention and experience of using the metaverse. *JAHR, 13*(1), 177–192. https://doi.org/10.21860/j.13.1.10

Levac, D., Colquhoun, H., & O'Brien, K. K. (2010). Scoping studies: Advancing the methodology. *Implementation Science, 5*(1), Article 69. https://doi.org/10.1186/1748-5908-5-69

Lévy, P., & Zapata-Ros, M. (2023). Visions of three-dimensional or virtual workspaces, metaverses, and education: Virtual reality and learning. *Revista de Educación a Distancia, 23*(73). https://doi.org/10.6018/red.554591

Li, M., & Yu, Z. (2023). A systematic review on the metaverse-based blended English learning. *Frontiers in Psychology, 13*. https://doi.org/10.3389/fpsyg.2022.1087508

Lin, H., Wan, S., Gan, W., Chen, J., & Chao, H.-C. (2022). Metaverse in education: Vision, opportunities, and challenges. *arXiv*. https://doi.org/10.48550/arXiv.2211.14951

Lombeyda, S., Djorgovski, S. G., Tran, A., Liu, J., Noyes, A., & Fomina, S. (2022). An open, multi-platform software architecture for online education in the metaverse. *arXiv*. https://doi.org/10.48550/arXiv.2211.05199

López-Belmonte, J., Pozo-Sánchez, S., Carmona-Serrano, N., & Moreno-Guerrero, A.-J. (2022). Flipped learning and e-learning as training models focused on the metaverse. *Emerging Science Journal, 6*(Special Issue), 188–198. https://doi.org/10.28991/ESJ-2022-SIED-013

Mirault, J., Serna, A., & Bailly, G. (2023). Assessing reading fluency in primary school children using virtual reality: The VR-IA study. *Frontiers in Education, 8*.

Muthmainnah, A., Al Yakin, A., & Seraj, P. M. I. (2023). Impact of metaverse technology on student engagement and academic performance: The mediating role of learning motivation. *International Journal of Computations, Information, and Manufacturing, 3*(1), 11–18. https://doi.org/10.54489/ijcim.v3i1.234

Park, S., & Kim, S. (2022). Identifying world types to deliver gameful experiences for sustainable learning in the metaverse. *Sustainability, 14*(3), Article 1361. https://doi.org/10.3390/su14031361

Rahman, H., Wahid, S. A., Ahmad, F., & Ali, N. (2024). Game-based learning in metaverse: Virtual chemistry classroom for chemical bonding for remote education. *Education and Information Technologies, 29*, 19595–19619. https://doi.org/10.1007/s10639-024-12575-5

Rojas, E., Hülsmann, X., Estriegana, R., Rückert, F., & Garcia-Esteban, S. (2023). Students' perception of metaverses for online learning in higher education: Hype or hope? *Electronics, 12*(8), Article 1867. https://doi.org/10.3390/electronics12081867

Sá, M. J., & Serpa, S. (2023). Metaverse as a learning environment: Some considerations. *Sustainability, 15*(3), Article 2186. https://doi.org/10.3390/su15032186

Said, G. R. E. (2023). Metaverse-based learning opportunities and challenges: A phenomenological metaverse human-computer interaction study. *Electronics, 12*(6), Article 1379. https://doi.org/10.3390/electronics12061379

Salloum, S., Al Marzouqi, A., Alderbashi, K. Y., Shwedeh, F., Aburayya, A., Al Saidat, M. R., & Al-Maroof, R. S. (2023). Sustainability model for the continuous intention to use metaverse technology in higher education: A case study from Oman. *Sustainability, 15*(6), Article 5257. https://doi.org/10.3390/su15065257

Sisamud, K., Chatwattana, P., & Piriyasurawong, P. (2023). The project-based learning using design thinking model via metaverse to enhance Buddhism innovators. *Higher Education Studies, 13*(3), 10–17. https://doi.org/10.5539/hes.v13n3p10

Smith, S., & Jones, L. (2023). Ethical considerations in metaverse-based education. *Journal of Educational Technology & Society, 26*(1), 45–57.

Sripan, T., & Jeerapattanatorn, P. (2022). Exnovation: The ultimate development of innovation and roles of metaverse in education and training in the next normal era. *Journal of Innovation and Management, 7*(2), 174–188.

Srisawat, S., & Piriyasurawong, P. (2022). Metaverse virtual learning management based on gamification techniques model to enhance total experience. *International Education Studies, 15*(5), 153–163. https://doi.org/10.5539/ies.v15n5p153

Tlili, A., Huang, R., Shehata, B., Liu, D., Zhao, J., Metwally, A. H. S., & Burgos, D. (2023). Metaverse in education: A systematic review and research agenda. *Computers and Education: Artificial Intelligence, 4*, Article 100074.

Ullah, H., Manickam, S., Obaidat, M., Laghari, S. U. A., & Uddin, M. (2023). Exploring the potential of metaverse technology in healthcare: Applications, challenges, and future directions. *IEEE Access, 11*, 69686–69707. https://doi.org/10.1109/ACCESS.2023.3286696

Wang, Y., Lee, L.-H., Braud, T., & Hui, P. (2022). Re-shaping post-COVID-19 teaching and learning: A blueprint of virtual-physical blended classrooms in the metaverse era. *arXiv*. https://doi.org/10.48550/arXiv.2203.09228

Yu, W., Chua, T. J., & Zhao, J. (2023). Asynchronous hybrid reinforcement learning for latency and reliability optimization in the metaverse over wireless communications. *IEEE Journal on Selected Areas in Communications, 41*(7), 2138–2157. https://doi.org/10.1109/JSAC.2023.3280988

Zen, A. P., & Hidayat, S. (2022). The potential of mixed reality in online practicum learning. *Jurnal Sosioteknologi, 21*(3), 242–249. https://doi.org/10.5614/sostek.itbj.2022.21.3.2

Zhang, Q. (2023). Secure preschool education using machine learning and metaverse technologies. *Applied Artificial Intelligence, 37*(1), Article e2222496. https://doi.org/10.1080/08839514.2023.2222496

Zhou, F., & Kim, D. J. (2022). Development of a metaverse-based smart education ecosystem. *Applied Sciences, 12*(3), Article 1234. https://doi.org/10.3390/app12031234

APPENDIX A

Table A1. Summary of selected studies (organized by year and alphabetical order)

Reference	Focus area	Methodology	Key findings
Almarzouqi et al. (2022)	User intention to use metaverse in medical education	SEM-ML hybrid analysis; survey (1,858 participants)	Found that user satisfaction is the most critical determinant of metaverse adoption. Developed a hybrid SEM-ANN model for predictive analysis.
Asfarian et al. (2022)	The gap between immersive technologies and mature metaverse in agriculture education	Systematic literature review	Identified underutilization of metaverse design elements, implementation gaps, and high complexity and costs for mature adoption. Recommended long-term planning and use case identification.
Dahan et al. (2022)	Framework for metaverse-based e-learning	Framework development	Proposed a metaverse framework (ELEM) integrating virtual, augmented, and extended reality for interactive learning; highlighted the need for robust infrastructure and cloud-based solutions.
Gonçalves et al. (2022)	Using metaverse to teach and promote cultural heritage	Case study; heuristic evaluation	Virtual recreation of Amiais village in Second Life promoted cultural learning and engagement. Users were motivated to visit the real location. Highlighted challenges in navigation and motivation during tasks.
Indarta et al. (2022)	Challenges and opportunities of metaverse in education	Narrative review	Found that metaverse can address limitations of traditional education, such as class capacity and geographical constraints, while emphasizing challenges like infrastructure, accessibility, and privacy.
Jovanović and Milosavljević (2022)	Gamified collaborative learning in metaverse platforms	Comparative analysis; user testing	Developed the VoRtex platform, integrating gamification and collaboration features. Showed improved learning outcomes and engagement through a MicroLesson feature.
Lee (2022)	Intention and experience of using metaverse among college students	Survey (502 participants)	Found positive intention to use the metaverse among MZ generation despite limited prior experience; highlighted potential applications in education and social interaction.
Lee and Hwang (2022)	VR and metaverse integration for teacher readiness and K-12 sustainable learning	Mixed methods: Pre/post surveys, reflection analysis	VR-making and metaverse-linking improved pre-service teachers' technological readiness, creativity, and collaboration. Identified barriers like technical expertise and digital divide.
López-Belmonte et al. (2022)	Flipped learning and e-learning for metaverse readiness	Quasi-experimental design (pre-post)	Found that flipped learning excels in teaching and learning environments, while e-learning enhances critical thinking and academic outcomes.
Park and Kim (2022)	Identification of world types for sustainable learning in the metaverse	Bottom-up case analysis of real metaverse environments	Identified five world types (survival, maze, multi-choice, racing/jump, escape room) promoting sustainable learning via gameful experiences.
Srisawat and Piriyasurawong (2022)	Metaverse learning management using gamification techniques	Model development; expert validation	Developed MVLM-Gt model integrating gamification and active learning theory. Experts rated the model as excellent for enhancing student engagement and total learning experience.
Zen and Hidayat (2022)	Potential and challenges of mixed reality in online practicum learning	Literature review; case studies	Identified how AR and VR integration in MR addresses gaps in practicum learning by enabling hands-on experiences and interactive collaboration, while highlighting technological barriers.
Al-Adwan et al. (2023)	Factors influencing adoption of metaverse-based platforms in higher education	Extended TAM model; PLS-SEM analysis	Identified perceived usefulness, personal innovativeness, and enjoyment as key enablers, while cyber risk is a major inhibitor.
Buckley et al. (2023)	Opportunities and challenges for metaverse in learning development	Workshop-based exploration	Identified key ethical concerns, inclusive challenges, and implications for educational practices; emphasized co-creation and practical discussions.

Table A1 (Continued).

Reference	Focus area	Methodology	Key findings
Chamorro-Atalaya et al. (2023)	Success factors of metaverse in university education during COVID-19	Systematic literature review	Identified virtual reality as the most used type of metaverse. Highlighted improved academic performance and interaction among students in medical, engineering, and administration fields.
Chen et al. (2023)	Contributors, cooperations, and thematic development in educational metaverse	Bibliometrics; topic modeling	Identified 8 themes in educational metaverse research, including physical education, language learning, STEM education, and autism support. Highlighted challenges such as data privacy and preparing instructors.
De Felice et al. (2023)	Role of metaverse in education	Systematic literature review (PRISMA)	Identified immersive, interactive learning opportunities while highlighting challenges like ethical concerns and accessibility issues.
Dong and Lee (2023)	Multimedia communication requirements for XR-based metaverse	Conceptual analysis	Discussed bandwidth, latency, and quality of experience metrics essential for immersive XR systems in education and other applications.
Firdaus (2023)	BYOD-connected cyber metaverse platform in Indonesian education	Netnography; grounded theory	Highlighted the lack of a unified platform for digital learning; proposed BYOD-connected cyber metaverse as a solution to unify and enhance digital participation and creativity.
Hambali et al. (2023)	Use of Gather Town for distance education in virtual learning environments	Quantitative study; correlation analysis	Found that Gather Town enhances engagement and interaction in virtual learning environments. Addressed challenges in accessibility and customization.
Han et al. (2023)	Systematic review on Roblox-based learning	Systematic literature review (PRISMA & LDA topic modeling)	Identified Roblox as a platform supporting social interaction, collaborative learning, STEM education, and VR-supported learning. Highlighted challenges like cyberbullying and teaching design issues.
Kaddoura and Al Husseiny (2023)	Challenges and opportunities in metaverse education	Systematic literature review (PRISMA)	Explored immersive technology for education, emphasizing benefits like gamification and skill-based learning, alongside ethical and technical challenges.
Lévy and Zapata-Ros (2023)	Theoretical reflections on metaverse applications in education	Special issue editorial synthesis	Highlighted gaps in empirical research, emphasizing VR and metaverse as tools for enhancing traditional symbolic systems like computational thinking and literacy.
Li and Yu (2023)	Blended English learning in the metaverse	Systematic literature review (PRISMA)	Explored the role of immersive virtual environments in enhancing learner engagement, digital literacy, and learning outcomes, while identifying challenges like digital divide and technical literacy.
Muthmainnah et al. (2023)	Impact of metaverse on student engagement and performance	Empirical research (survey & SEM)	Found positive effects of metaverse on engagement and academic performance, mediated by learning motivation; highlighted accessibility and strategy gaps.
Rojas et al. (2023)	Perception of metaverse for online higher education	Quantitative survey (52 engineering students)	Students positively rated ease of use, immersion, and fun but were neutral on usefulness and interaction compared to face-to-face learning. Highlighted challenges in interaction and cost.
Sá and Serpa (2023)	Metaverse as a learning environment	Qualitative (content analysis)	Explored the challenges and opportunities of metaverse education, including ethical issues, accessibility concerns, and the integration of immersive technologies.
Said (2023)	HCI challenges and opportunities in MBL	Phenomenological study	Identified five challenges (e.g., immersive design & privacy issues) and three opportunities (e.g., hands-on training, game-based learning) for meta-education.

Table A1 (Continued).

Reference	Focus area	Methodology	Key findings
Salloum et al. (2023)	Sustainability model for metaverse adoption in higher education	Online survey (953 participants)	Identified perceived value, enjoyment, innovativeness, and ubiquity as key factors driving adoption. Highlighted the moderating role of innovativeness in user behavior.
Sisamud et al. (2023)	Integration of project-based learning and design thinking via metaverse for enhancing Buddhist innovators	Research and development; expert validation	Developed a project-based learning model combining design thinking and metaverse; model found effective for independent learning and innovation in Buddhism propagation.
Ullah et al. (2023)	Applications of metaverse in healthcare	Systematic review	Explored AR/VR applications in healthcare including medical training, remote diagnostics, and patient engagement; identified technological and ethical challenges.
Yu et al. (2023)	Optimization of latency and reliability in metaverse applications	Reinforcement learning (AAHC model)	Proposed an AAHC model for optimizing UL-DL transmission in XR-based metaverse, achieving significant improvements in energy efficiency, delay reduction, and transmission reliability.
Zhang (2023)	Use of ML and metaverse for secure preschool education	Framework development; literature review	Proposed integrating ML for personalized learning and metaverse for immersive experiences; emphasized robust cybersecurity measures for safety.
Cai (2024)	Effectiveness of MBL in business education	Systematic review (PRISMA)	Found that metaverse improves learning outcomes and practical business skills but identified challenges like cost and lack of pedagogy.
Onu et al. (2024)	Potential of metaverse for teaching and learning	Qualitative study (literature review and interviews)	Highlights the immersive and interactive potential of metaverse for personalized learning while identifying challenges like technical infrastructure and privacy concerns.
Rahman et al. (2024)	Game-based immersive learning for middle school chemistry	Randomized controlled trial (90 participants)	Found VR-enhanced methods outperform traditional and online methods in engagement and learning outcomes; usability highly rated by students.