Contemporary Educational Technology, 2025, **17**(4), ep593
ISSN: 1309-517X (Online)

OPEN ACCESS

Review Article

The current status and contributing factors of the metaverse adoption in education: A systematic review

Jiayan Xie [1]
0009-0000-9082-457X

Ghayth K. S. Al-Shaibani [2*]
0000-0003-4399-6824

Jingli Zhao [3]
0009-0005-3069-2778

Othman Talib [1]
0000-0002-5284-5924

[1] Department of Education, Faculty of Social Sciences and Liberal Arts, UCSI University, Kuala Lumpur, MALAYSIA
[2] Institute of Languages, UCSI University, Kuala Lumpur, MALAYSIA
[3] School of Computer and Artificial Intelligence, Anhui Technical College of Industry and Economy, Hefei, CHINA
[*] Corresponding author: ghayth@ucsiuniversity.edu.my

Citation: Xie, J., Al-Shaibani, G. K. S., Zhao, J., & Talib, O. (2025). The current status and contributing factors of the metaverse adoption in education: A systematic review. *Contemporary Educational Technology, 17*(4), ep593. https://doi.org/10.30935/cedtech/17301

ARTICLE INFO

Received: 9 Nov 2024
Accepted: 29 Aug 2025

ABSTRACT

The application potential of the metaverse as an emerging technology in education has sparked widespread attention globally. A systematic review was conducted using the preferred reporting items for systematic reviews and meta-analyses method, which yielded 43 relevant articles from a total of 527 articles to examine the current status and the potential of the metaverse adoption in education. The analysis involves seven aspects as reflected in the seven research questions posed. The results indicate global widespread interest in exploring the potential application of the metaverse in education, primarily focusing on general educational settings and relatively less on specific subjects such as English and mathematics. Surveys and interviews were the primary research methods used, with the technology acceptance model and the unified theory of acceptance and use of technology as common theoretical frameworks. Twenty-five factors influencing the adoption of the metaverse in education have been identified, and six future research topics, such as examining students' and teachers' behaviors and attitudes have been proposed. This review contributes to constructing a novel framework for future research of the metaverse adoption in education, encouraging educators to integrate its advantages into specific subjects based on students' needs for quality education.

Keywords: the educational metaverse, the metaverse adoption framework, contributing factors, quality education

INTRODUCTION

Owing to students' needs in the utilization of technology, digital transformation has become a key driver of educational innovation (Kaputa et al., 2022; Wang et al., 2023a). Moreover, the emergence of the metaverse has provided unprecedented opportunities for quality education (Dwivedi et al., 2022; Lin et al., 2022; Onu et al., 2024). The metaverse redefines the ways of learning and teaching by creating immersive, interactive virtual environments (Hwang et al., 2023b; Saritas & Topraklikoglu, 2022; Wang et al., 2023b). As an amalgamation of cutting-edge technologies (Estudante & Dietrich, 2020; Xu et al., 2023) such as augmented reality (AR), virtual reality (VR), blockchain, and artificial intelligence (AI), the metaverse brings innovative teaching methods, learning models, and interactive experiences to education (Park & Kim, 2022b; Tlili et al., 2022; Wang et al., 2022).

Research on metaverse-based applications is gradually increasing, focusing on aspects such as technology adoption (Pan et al., 2023; Yang et al., 2022), educational impacts (Xu et al., 2024; Yang et al., 2024), application domains (Chen, 2022), and ethical considerations (Di Pietro & Cresci, 2021; Kaddoura & Al Husseiny, 2023). Al-Adwan et al. (2023) expanded technology acceptance model (TAM) to examine the metaverse adoption in education. Al-Adwan and Al-Debei (2024) focused on generation Z's adoption determinants, while Parmaxi (2023) explored VR use in language learning. These studies collectively highlight the growing integration of the metaverse in diverse educational settings. İbili et al. (2023) explored learners' behavioral intentions to use the metaverse through a survey, while Di Natale et al. (2024a) focused on the acceptance and sustained usage of immersive VR technology in education. Saritas and Topraklikoglu (2022) found that most studies were descriptive, aiming to describe the concepts and characteristics of the metaverse environment rather than establishing causal relationships. Chen et al. (2023a) utilized social network visualization and bibliometric analysis to reveal the primary publishing journals, countries or regions, institutions, and research topics in educational metaverse studies. Tlili et al. (2022) combined content analysis and bibliometric analysis to explore the applications, challenges, and impacts of the metaverse in education. Chua and Yu (2024) focused on the diversity of metaverse-based applications in education and highlighted the importance of perceived usefulness (PU) and perceived ease of use (PEOU) in the acceptance. Roy et al. (2023) proposed a framework for the metaverse in education, analyzing publishing trends, applications, and challenges. **Appendix A** provides a summary of the most recent reviews from 2022 to 2024 that are related to the adoption of the metaverse in education.

The existing review studies have explored the application of the metaverse in education and its potential impacts. However, there is a relative lack of systematic reviews on the factors influencing its adoption. Although the existing studies explored individual factors in fields such as technology, education, psychology, and society, they often lack a comprehensive approach that integrates these factors to provide a holistic perspective. Additionally, the analyses of theoretical foundations, models, and key factors influencing the adoption of the metaverse in education appear to be insufficient. While much of the research has focused on general educational settings, exploration is insufficient as how the metaverse can be effectively integrated into specific subjects, such as science, engineering, or humanities. Moreover, the analysis of the primary target groups involved in metaverse-based learning is relatively scarce. Therefore, this review aims to systematically examine the relevant literature to uncover the research trends, common research methods, primary disciplines, and target groups, as well as to identify the main factors influencing the metaverse adoption in education. Additionally, it seeks to examine the models and theories used in the reviewed studies to propose a new framework and suggest future directions for metaverse research in education. To achieve such objectives, this review poses the following seven research questions (RQs):

RQ1: What are the research trends on the metaverse in education in the studies reviewed?

RQ2: What research methods are used in the studies reviewed?

RQ3: What are the primary disciplines of the studies reviewed?

RQ4: What are the most frequent target groups in the studies reviewed?

RQ5: What models or theories are used in the studies reviewed?

RQ6: What factors influence the adoption of the metaverse in education?

RQ7: What are the future researchable topics/themes and questions of the metaverse in education?

To highlight the contribution of this study, through the analysis and synthesis of the research questions, this review not only unveils the research trends, research methods, models/theories and the influential factors of educational metaverse adoption but also pinpoints the existing research gaps by constructing a novel framework for future research. Moreover, it suggests interdisciplinary communication and collaboration across various academic domains, thus fostering the advancement of some disciplines in the metaverse.

Table 1. Inclusion and exclusion criteria for data selection

No	Inclusion criteria	Exclusion criteria
Time range	January 2021-February 2024	Published before 2021
Scope	Articles that explore education within the metaverse or metaverse-based platforms	Articles discussing the metaverse or metaverse-based platforms unrelated to education
Types	Journal or conference papers containing theoretical frameworks, research methodologies, or influential factors	Papers consisting solely of reviews or commentary without theoretical frameworks, research methodologies, or influential factors
Language	Articles written in English	Non-English articles

METHODS

This review adopts the preferred reporting items for systematic reviews and meta-analyses (PRISMA) method (Page et al., 2021) by selecting appropriate databases and search strategies along with the keywords and determining the target literature needed for the analysis of the research questions through inclusion and exclusion criteria to achieve the purpose of the review.

Search Strategy

Based on previous scholars' work, the review must be grounded in high-quality publications (Cassidy et al., 2021; Wolfswinkel et al., 2013). Given the early stage of the metaverse development, this review included all the relevant publications until February 2024. The search process employed Boolean logic operators (Jonsson & Tarski, 1951). To cover all metaverse-related literature as comprehensively as possible, the initial keywords used were ("Metaverse" OR "Augmented Reality" OR "Virtual Reality") AND (education OR teach* OR learn*) OR (factors OR determinants OR intention) in the Web of Science Core Collection, yielding a vast number of search results that were unrelated to the research topic. Hence, selecting appropriate keywords is fundamental to literature retrieval, and the suitable choice of keywords is crucial for identifying the relevant literature to be included in a systematic review (Alfaisal et al., 2024). Therefore, the researchers narrowed the search scope by removing the keywords ("Augmented Reality" OR "Virtual Reality") because they are not related to our research topic and focused on keywords closely related to the topic as *metaverse, teaching, learning*, and *influencing factors*. Ultimately, the search keywords were refined to "metaverse AND (education OR teach* OR learn* OR factors OR determinants OR intention)".

Databases and Data Sources

The researchers selected the Web of Science Core Collection, including *IEEE, Springer, Taylor & Francis, Elsevier, Sage, ACM Digital Library, Emerald,* and *Wiley Online Library* because these databases and publishers are widely recognized in the international research community, which publish peer-reviewed articles, ensuring a relatively high-quality content and the reliability of the results. The selection was also based on their widespread recognition and high impact within the academic community, particularly relevant to the metaverse in education. However, potential bias exists due to the exclusion of other databases, and broader coverage in future research could help mitigate limitations and provide a more comprehensive analysis.

Through the search using the finalized keywords, a total of 527 articles was found across the selected databases in the following distribution: IEEE (216), Springer (85), ScienceDirect (82), Taylor & Francis (42), Emerald (38), Wiley (32), ACM (20), and SAGE (12).

Inclusion and Exclusion Criteria

The selection of articles was based on the inclusion and exclusion criteria outlined in **Table 1**. Initially, reviews, books, book chapters, editorial materials, and non-English publications (n = 84) were excluded based on the criteria and thus yielding 443 articles. After that, the articles which are not related to education in the metaverse were also excluded based on titles, keywords, and abstracts, resulting in the exclusion of n = 49 articles. After careful reading and discussion, the two researchers agreed to exclude 9 articles that lacked a theoretical foundation, research methods, or an analysis of influential factors, leaving 40 articles. During the full-text reading process, an additional 3 relevant articles that align with the research objectives and questions

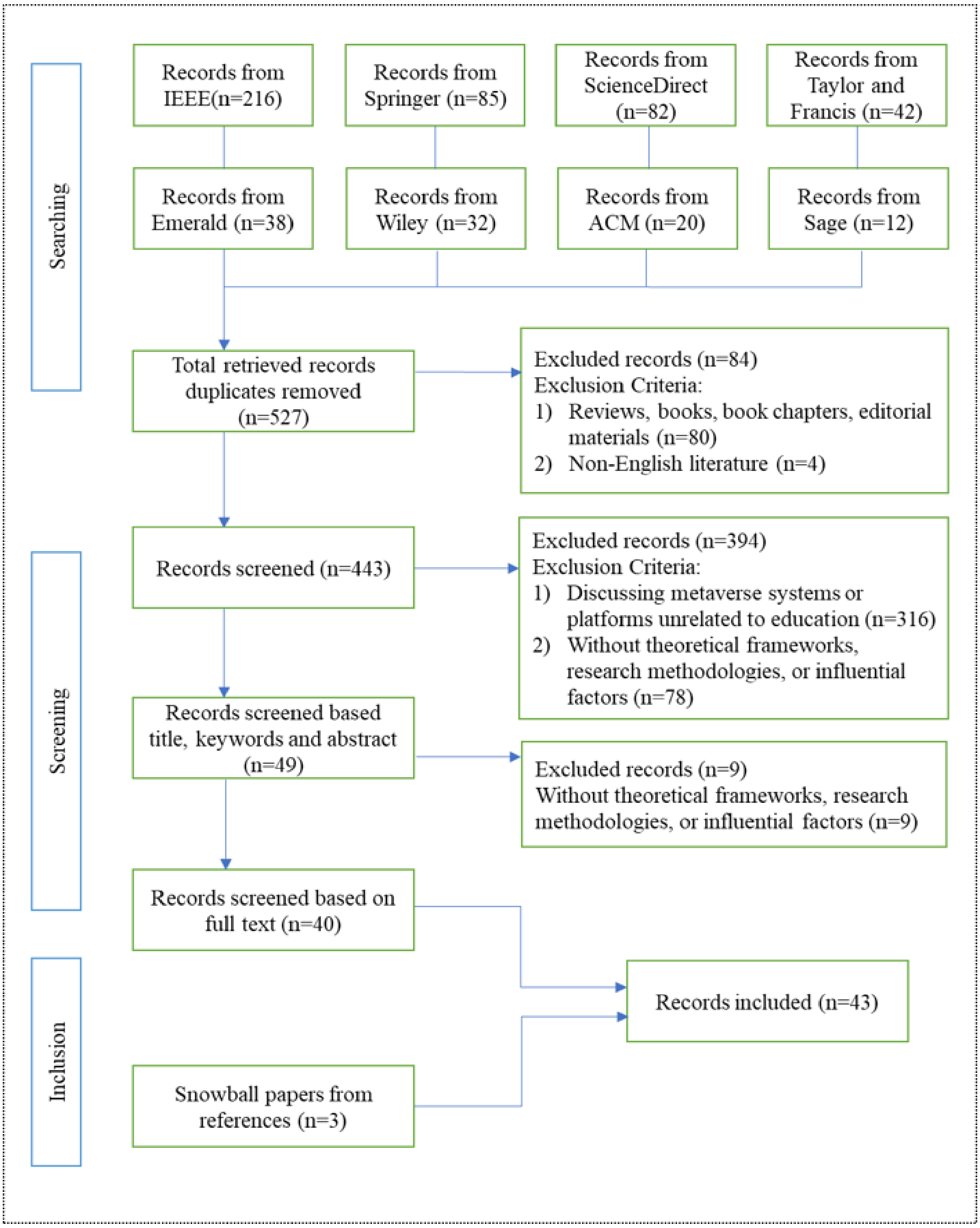

Figure 1. The adapted PRISMA flowchart of the selection process [Source: Authors' own creation based on Page et al. (2021)]

were found in the references of the included articles and hence have been added. Therefore, a total of 43 studies were included, primarily peer-reviewed journal articles, along with four relevant conference papers (three IEEE, one ACM), published between 2021 and 2024. Grey literature was excluded to maintain academic rigor and reliability.

Selection Criteria and Process

For the selection process, two researchers independently screened and evaluated the articles. Discrepancies were resolved by consulting a third author. The inter-rater reliability (k = 0.71) indicated an acceptable level of agreement (Pérez et al., 2020). A total of 43 articles were ultimately included in the systematic review. The entire search and selection process followed the PRISMA guidelines (Page et al., 2021), as depicted in **Figure 1**.

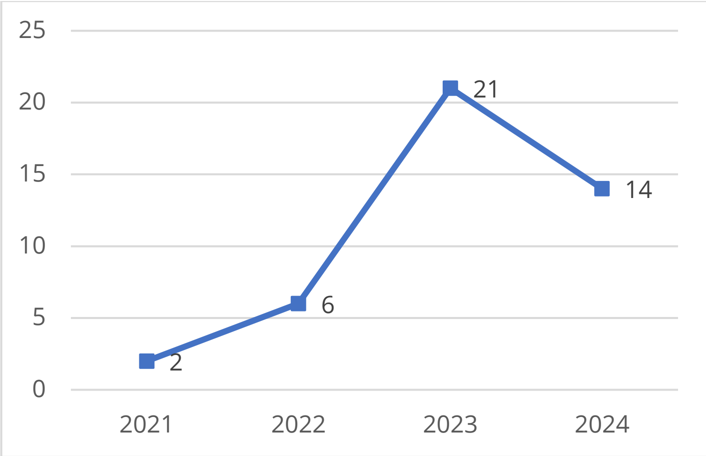

Figure 2. Years of publications (Source: Created by authors based on the included studies)

RESULTS

Through data decoding, this systematic review presents the results of data analysis based on the following seven aspects:

(1) year, country and journal distribution,

(2) research and analysis methods,

(3) disciplines and scenarios involved,

(4) target research groups,

(5) models or theories,

(6) factors influencing the adoption or acceptance of the metaverse, and

(7) future research topics/themes.

RQ1. What Are the Research Trends on the Metaverse in Education in the Studies Reviewed?

The research trends of the reviewed studies can be reflected through years, countries and journals of publications (Alfaisal et al, 2024). The metaverse has become one of the highly researched areas in recent years, particularly experiencing rapid growth after 2021. The literature that meets the research requirements is predominantly from 2021 onwards. This is because there were relatively few published papers before this period, but as time progresses, more studies have been published. In 2022 and 2023, both academia and industry have actively engaged in exploring the metaverse, driving rapid development in this field as presented in **Figure 2**. Researchers have delved into the definition, construction methods, technical challenges, and potential application areas of the metaverse. This is possibly due to the increasing interest in this field and thus seeking new learning ventures.

In **Figure 3**, the distribution indicates significant involvement of Asian countries in research on the metaverse in education, particularly China (n = 8), South Korea (n = 8), Jordan (n = 5), and Turkey (n = 4). Additionally, contributions from Europe (n = 4), North America (n = 2), and other regions signify that the metaverse in education is a globally recognized research topic. The association between countries and literature is not one-to-one; for instance, the study by Pan et al. (2023) encompasses China and South Korea, while research by Pal et al. (2023) spans India and Thailand. Furthermore, there are some papers (n = 4) where the country is not explicitly mentioned.

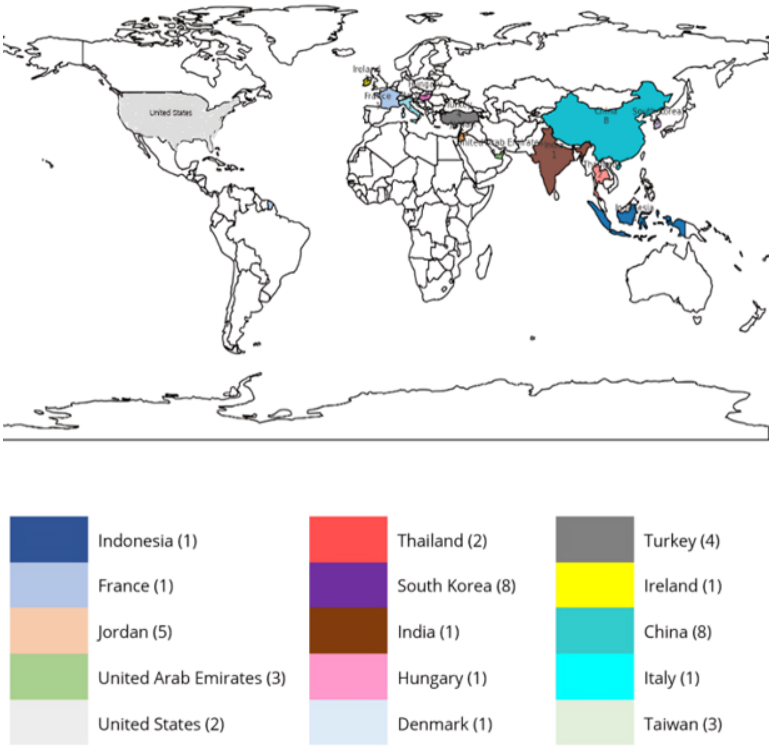

Figure 3. Countries of publications (Source: Created by authors based on the included studies)

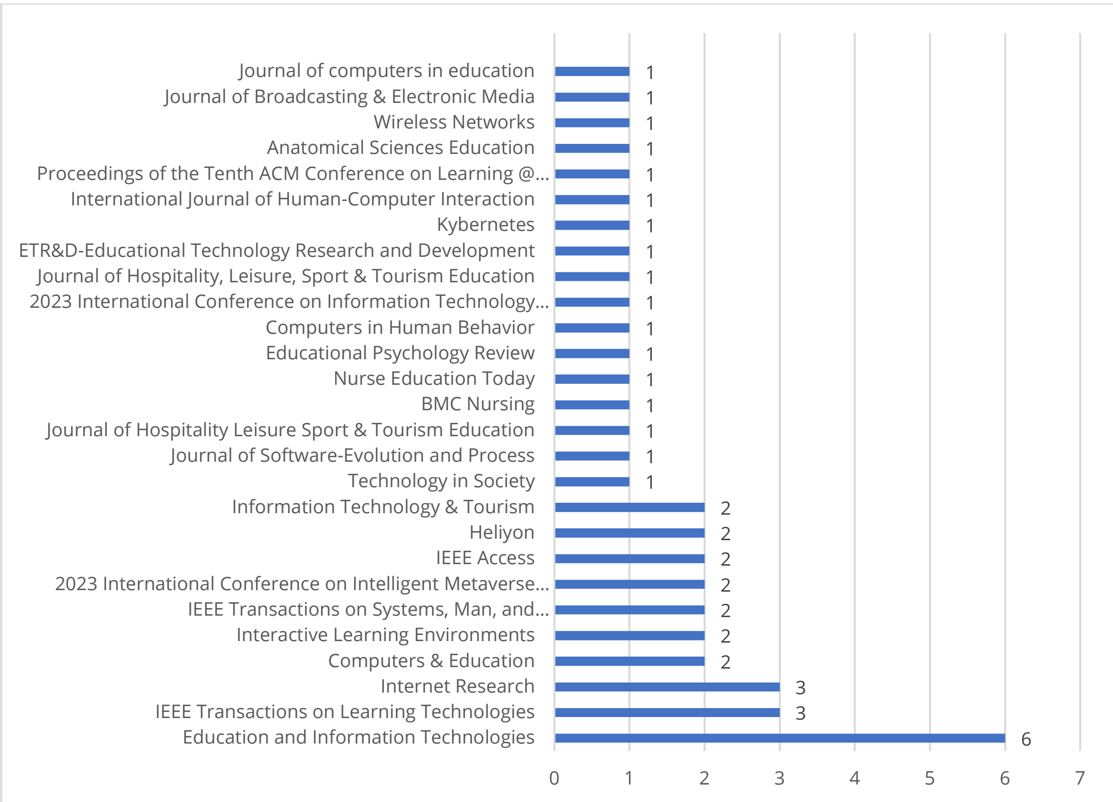

Figure 4. Journals of publications (Source: Created by authors based on the included studies)

The literature selected for this review is sourced from 27 authoritative journals, with prominent publications shown in **Figure 4**. This distribution indicates that research outcomes in educational metaverse are disseminated across various fields and journals, with *Education and Information Technologies* being the most prolific journal in publishing such studies (Al-Adwan & Al-Debei, 2024; Al-Adwan et al., 2023; Chen, 2024;

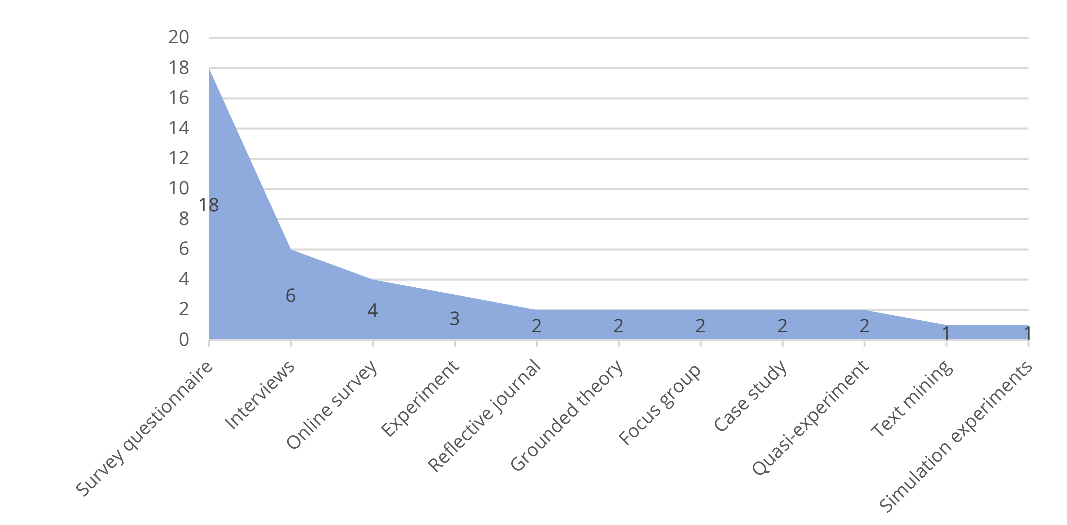

Figure 5. The primary research methods (Source: Created by authors based on the included studies)

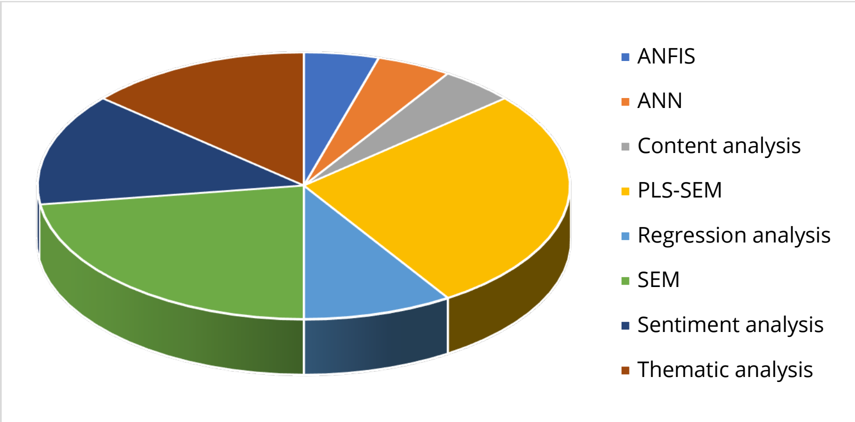

Figure 6. The primary analysis methods (Source: Created by authors based on the included studies)

Di Natale et al., 2024a; Wiangkham & Vongvit, 2024; Yang et al., 2024). Additionally, journals covering multiple domains such as *IEEE Access* (Almarzouqi et al., 2022; Siyaev & Jo, 2021), *Internet Research* (Lee & Chaney, 2024; Oh et al., 2024; Xu et al., 2024), and *Computer & Education* (Hwang, 2023; Hwang et al., 2023a) also demonstrate a high level of interest in this topic. This reflects the interdisciplinary nature of the metaverse in education as a research field, attracting widespread academic attention.

RQ2. What Research Methods Are Used in the Studies Reviewed?

In the educational metaverse, research methods, including data collection and analysis methods, demonstrate a diverse trend. As shown in **Figure 5**, survey questionnaire research (n = 18) stands out as the most common method, showcasing its effectiveness in large-scale data collection, enabling the gathering of broad perspectives, attitudes, and self-reported information from target populations. Following the survey research is the interview (n = 6), which allows for in-depth data collection of interviewees' insights. Additionally, the combination of online surveys (n = 4), especially when integrated with the PLS-SEM method, has been utilized in several studies (Kalınkara & Özdemir, 2024; Kim & Lee, 2023; Sediyaningsih et al., 2023; Wu & Yu, 2024), highlighting the convenience of data collection via online platforms and the demand for complex statistical analyses. Other methods, such as experiments (Makransky & Mayer, 2022), focus groups (Sin et al., 2023), grounded theory (Lee & Jo, 2023; Yilmaz et al., 2023), quasi-experiments (Chen, 2024; Hwang, 2023), text mining (Oh et al., 2024) and reflective journals (Lee et al., 2023), are less frequently used.

Past research employed diverse and analytical analysis methods, as shown in **Figure 6**. PLS-SEM serves as the primary analytical tool, widely used for handling complex variable relationships and validating research model assumptions. Regression analysis and multivariate statistical analysis play a crucial role in determining

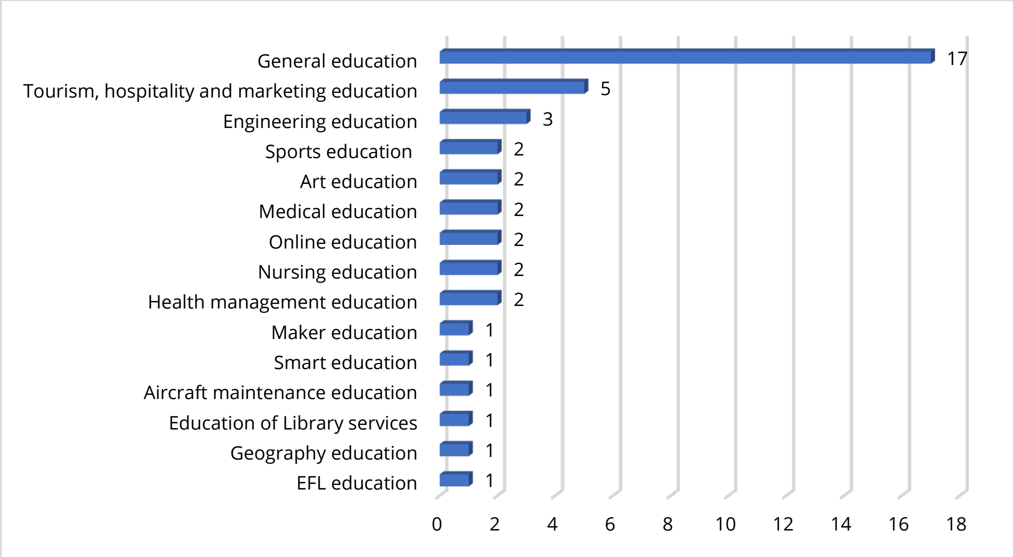

Figure 7. The primary disciplines/scenarios (Source: Created by authors based on the included studies)

relationships between variables and their impact, particularly in handling survey data, and are therefore frequently applied in the literature (Alhalaybeh & Althunibat, 2023; Xu et al., 2024). Qualitative data analysis methods, such as thematic analysis (Lee & Chaney, 2024; Lee & Jo, 2023; Lee et al., 2023), content analysis (Baker et al., 2023), sentiment analysis (Hwang, 2023; Hwang et al., 2023b; Oh et al., 2024), and case study analysis (Hare & Tang, 2022) are less commonly used. This may suggest a lower utilization of these qualitative analysis methods throughout the literature reviewed. In addition to traditional statistical analysis, some studies also employed advanced data analysis techniques such as artificial neural networks (ANN) (AlDhanhani et al., 2023) and adaptive neuro-fuzzy inference systems (ANFIS) (Wiangkham & Vongvit, 2024).

RQ3. What Are the Primary Disciplines of the Studies Reviewed?

This review's analysis of the metaverse in education reveals several key trends of research disciplines as demonstrated in **Figure 7**. The general education domain (n = 17) emerged as the most researched area, indicating that the application and research of the educational metaverse are still predominantly focusing on the general education. There is relatively less in-depth research on specific disciplines, particularly in terms of innovating specific subject-learning experiences and teaching methods.

Referring to **Figure 7**, apart from general education, research in other disciplinary domains is relatively scarce, with fewer publications in each field. These disciplines include health management education (n = 2), medical education (n = 2), arts education (n = 2), business tourism education (n = 5), nursing education and career guidance (n = 2), engineering education (n = 3), and physical education (n = 2), demonstrating the preliminary exploration of educational metaverse research in specific disciplines. Thus, this distribution reveals that the application of the metaverse in education is gradually expanding to more diverse and specialized domains, although these explorations are still in their early stages of research. Furthermore, notable attention is drawn to Maker education (Hwang, 2023) and smart education (Zheng et al., 2022), reflecting the potential application of the metaverse in practical teaching and intelligent learning environments. While research in specific disciplines such as EFL education (Chen, 2024) and aircraft maintenance education (Siyaev & Jo, 2021) remains limited, this gap underscores the potential for more targeted and in-depth investigations. Such a lack may be partly due to the high costs of developing immersive platforms, with resources often directed toward science and vocational training where the metaverse's experiential advantages are more readily applicable.

RQ4. What Are the Most Frequent Target Groups in the Studies Reviewed?

Based on an analysis of **Figure 8**, college students (n = 28) are the most common target group in educational metaverse research, encompassing both undergraduate and postgraduate learners, including doctoral students. This trend suggests that the metaverse in education has received widespread attention

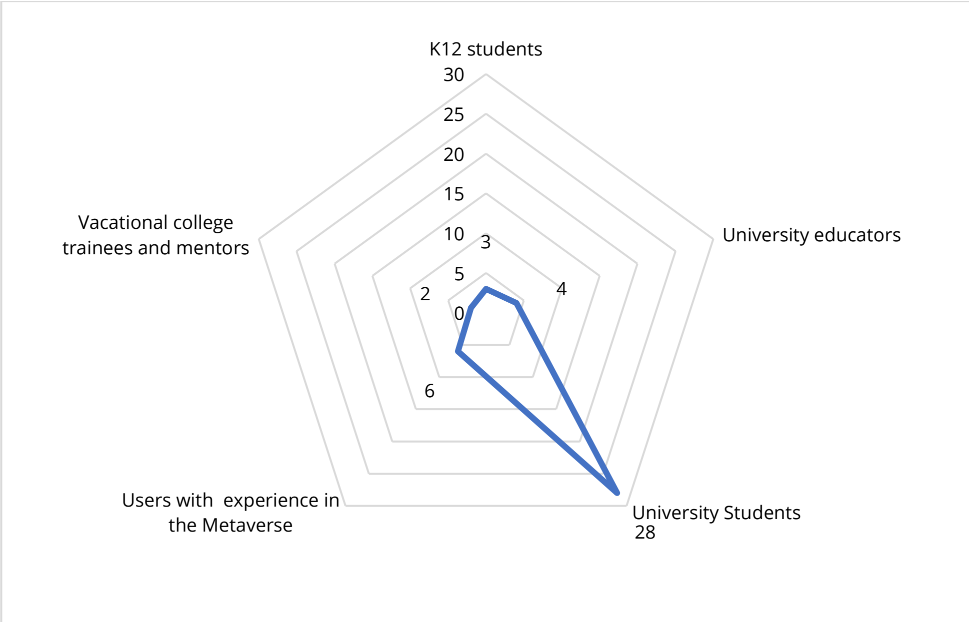

Figure 8. The target populations (Source: Created by authors based on the included studies)

and research in higher education as researchers have attempted to explore how the metaverse can enhance the learning experience and learning outcomes of college students (Hare & Tang, 2022; Li et al., 2024). In addition, educators and students at different educational levels, such as K-12 students (n = 3) (Xu et al., 2024; Yu, 2023) and pre-service teachers (Chen, 2024), have also become subjects of research, demonstrating that educational metaverse research covers a wide range of levels from basic education to higher education. It is worth noting that specific groups, such as disabled students (Hadi Mogavi et al., 2023) and individuals with specific professions, such as aviation students and industry professionals (Siyaev & Jo, 2021; Yilmaz et al., 2023), have also been included as target groups in research.

RQ5. What Models or Theories Are Used in the Studies Reviewed?

While TAM and unified theory of acceptance and use of technology (UTAUT) are the most commonly employed frameworks in educational metaverse research, several less frequently used or emerging models, such as GETAMEL, EECM, RBV, DOI, SDT, CoI, and CLT have also been identified. A comparative overview of these theoretical frameworks, including their application contexts and relevance is provided in **Appendix B**.

TAM and UTAUT were used by Al-Adwan et al. (2023), Ibili et al. (2023), Wiangkham and Vongvit (2024), Alkhwaldi (2024), and Wu and Yu (2024) to explore how users adopt and use the metaverse. Al-Adwan and Al-Debei (2024) and Yang et al. (2022) incorporated more influencing factors such as hedonic motivation and habit, demonstrating their strong adaptability in analyzing the adoption and usage behavior of higher education students in educational metaverse research. Additionally, several studies such as Hwang et al. (2023b), Lee et al. (2023) and Yilmaz et al. (2023) employed Experiential Learning Theory to commonly measure students' engagement in learning through immersive metaverse experiences. Meanwhile, GETAMEL (Ibili et al., 2023), ECM (Di Natale et al., 2024a), PPM (Pal et al., 2023), and flow theory (Wu & Yu, 2024; Yang et al., 2024) have been applied in specific studies, involving art education and a virtual computer laboratory in the metaverse.

DOI was used by Almarzouqi et al. (2022) and Pan et al. (2023) to predict user intention for adopting the metaverse in medical and general education. Although DOI has been applied in other technology adoption studies, its use in the educational metaverse field seems less common. The CoI framework was used by Song et al. (2023) to analyze the impact of metaverse-based platforms on teaching, social, and cognitive presence. While RBV and dynamic capabilities theory are more common in business and organizational strategy research (AlDhanhani et al., 2023), their application in the educational metaverse is relatively scarce. CLT was used by Kim and Lee (2023) to analyze distance perception and subjective experience in the performing arts in the metaverse. Oh et al. (2024) used perceived risk theory to examine how safety, identity, and emotional

Table 2. The 25 key influential factors from the most to the least frequent

No	Factors	Frequency
1	Perceived usefulness	14
2	Perceived ease of use	14
3	Perceived enjoyment	6
4	Self-efficacy	6
5	Social influence	5
6	Performance expectancy	5
7	Effort expectancy	5
8	Hedonic motivation	4
9	System quality	3
10	Information quality	3
11	Service quality	3
12	User satisfaction	3
13	Social presence	3
14	Personal innovativeness	3
15	Perceived behavioral control	2
16	Perceived compatibility	2
17	Perceived triability	2
18	Perceived observability	2
19	Perceived interaction	2
20	Facilitating conditions	2
21	Task-technology fit	2
22	Immersion	2
23	Engagement	2
24	Learning motivation	2
25	Knowledge construction	2

concerns affected user trust, satisfaction, and adoption of metaverse-based platforms. These models add depth and new perspectives to the understanding of the user acceptance, adoption, continued use, and experience of metaverse-based platforms in their unique application contexts in education.

RQ6. What Factors Influence the Adoption of the Metaverse in Education?

In this systematic review, many influencing factors have been identified, stemming from various theoretical models which construct frameworks for understanding how users accept and adopt new technologies. Among these models, some factors stand out prominently, indicating their importance in understanding and predicting technology acceptance. In adopting the educational metaverse, these factors are particularly crucial. **Table 2** presents the main 25 factors arranged from the most to the least frequent. Among them, *PU, PEOU, perceived enjoyment (PE), self-efficacy, social influence, effort expectancy, and performance expectancy* are the most common factors influencing the adoption of the metaverse in education. Meanwhile, the factors with the lowest frequency are *perceived behavioral control, perceived compatibility, perceived triability, perceived observability, perceived interaction, facilitating conditions, task-technology fit, immersion, engagement, learning motivation,* and *knowledge construction,* whereby each of these factors was mentioned only twice in the studies reviewed. By considering these factors, researchers and practitioners can better predict the adoption process of the metaverse in education.

RQ7. What Are the Future Researchable Topics/Themes and Questions of the Metaverse in Education?

Currently, research on the metaverse is still in its early stages, and the trend of research is showing continuous growth (Feng et al., 2024; Ren et al., 2022). Future research on the metaverse in education can be explored from multiple dimensions. Based on the studies by Arpaci and Bahari (2024), Chaipidech et al. (2021), Kaddoura and Al Husseiny (2023), Salloum et al. (2023), Singla et al. (2023), and Wu et al. (2023), the future possible research issues in the educational metaverse encompass six broad dimensions:

(1) behavior and attitude (students' and teachers' behavioral intentions and attitudes),

(2) technology safety and design (design and development of metaverse teaching content and methods, data privacy and security),

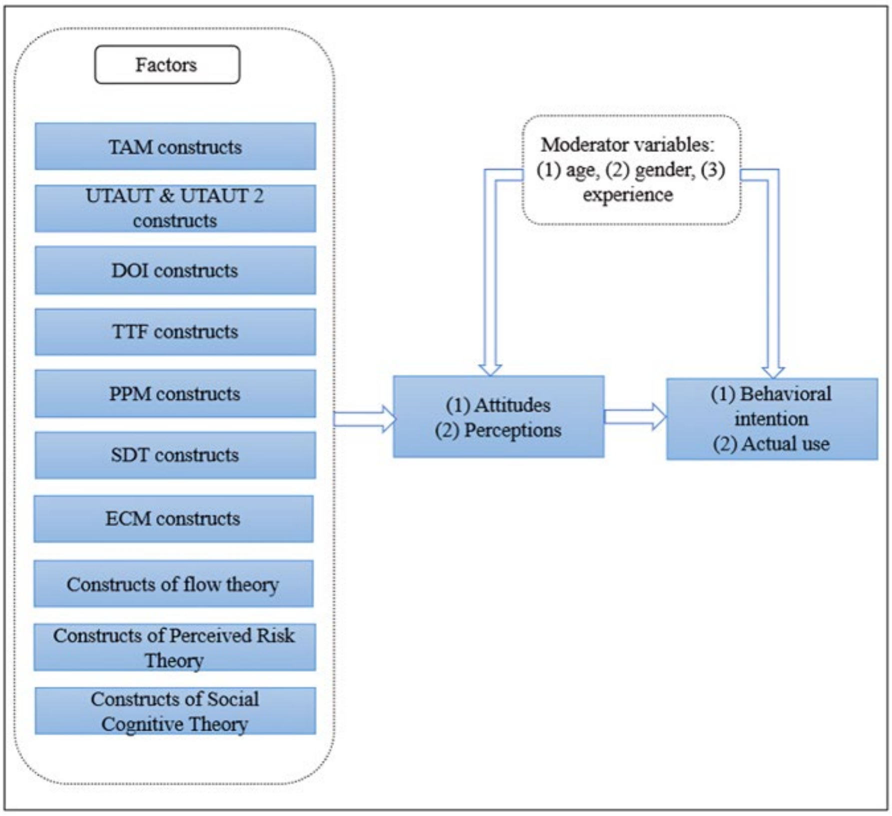

Figure 9. The proposed theoretical framework for the adoption of metaverse-based education (Source: Created by authors based on the included studies)

(3) teaching and learning (learner engagement, learning experiences, assessment of learning outcomes),

(4) society, culture, and ethics (ethical and social impacts; cross-cultural education),

(5) teacher training and support, and

(6) continuous learning and career development.

These directions not only reflect the integration of the metaverse and educational practice but also involve multidimensional issues related to ethics, society, and culture. The specific future research themes are summarized in **Appendix C**.

Behavior and attitudes

Research on students' and teachers' behavioral intentions and attitudes focuses on the acceptance of the metaverse by educational participants, which is a prerequisite for achieving educational goals (Chanda et al., 2024). Models such as TAM, UTAUT, UTAUT2, SDT, ECM, TPB, DOI, flow theory, TTF, and PPM can be applied (see **Figure 9**). Investigating differences in students' and teachers' attitudes towards the metaverse in education, changes in learning motivation and engagement before and after the introduction of the metaverse can contribute to understanding students' and teachers' perceptions, expectations, concerns, and possible obstacles when using it.

Technological safety and design

The design and development of metaverse-based instruction focus on leveraging the technology's distinctive features to enhance and innovate teaching content and pedagogy (Alam & Mohanty, 2022; Onu et al., 2024). This includes developing courses adapted to virtual environments, designing interactive and engaging learning activities, and using VR to provide immersive learning experiences. For example, using metaverse-based platforms, simulated historical event scenes or science laboratories can be created, allowing students to learn in almost real environments (Choi & Kim, 2017; Potkonjak et al., 2016), which can not only enhance learning motivation but also can deepen understanding and memory of scenarios.

Data privacy and security underscore the importance of protecting personal information and data in the metaverse (Di Pietro & Cresci, 2021; Wang et al., 2023b). With the popularity of metaverse-based platforms, students and teachers generate and share a large amount of data in these virtual spaces. Therefore, it becomes crucial to study how to implement effective data protection measures and policies in the metaverse environment to prevent unauthorized data access and leakage (Sripan & Jeerapattanatorn, 2025) and to ensure the legal use of data.

Teaching and learning

Learner engagement focuses on how to enhance learners' participation and involvement through the characteristics of the metaverse, such as interactivity and immersion (Han et al., 2023; Zhang et al., 2022). High levels of engagement in learning experiences are typically associated with better learning outcomes (Hsieh, 2014). In the metaverse, whether student engagement can be significantly enhanced through customized learning paths, interactive learning tasks, and collaborative projects needs to be researched in the future.

Learning experiences are concerned with the creation of new learning experiences in the metaverse and their impacts on learning outcomes (Park & Kim, 2022a). The metaverse provides a unique learning platform that can create immersive learning environments through technologies such as VR and AR (Beck et al., 2024; Di Natale et al., 2024b). Future research on learning experiences involves exploring how these technologies affect students' cognition, emotions, and social interactions, including differences in learners' experiences, satisfaction, and learning motivation. Understanding how these factors influence the learning process and outcomes is crucial for designing more effective learning environments.

Learning outcomes assessment aims to develop assessment methods and tools adapted to the characteristics of the metaverse in education (Huang et al., 2020; Shu & Gu, 2023). As teaching methods shift to virtual environments, traditional assessment methods may no longer be entirely applicable. Therefore, research is needed on how to effectively measure and assess students' learning outcomes in the metaverse, including knowledge mastery, skill development, innovation abilities, and critical thinking. This may involve developing new assessment tools, technologies, and evaluation criteria, as well as utilizing data analysis and AI to track and analyze learners' behaviors and outcomes, peer evaluation, and timely feedback.

Society, culture, and ethics

Ethical and social impacts explore the ethical challenges and social impacts that the metaverse may bring. This includes the influence on learners' identity recognition, behavioral norms in virtual environments, and potential digital divide issues (Wang et al., 2023b). In addition, the popularization of the metaverse may also trigger discussions on issues such as intellectual property rights, content censorship, and user safety (Bojic, 2022). Studying the issues listed in **Appendix C** helps develop reasonable policies and practices to ensure effective management and mitigation of the negative social impacts of the metaverse.

Cross-cultural education emphasizes how to use the global connectivity of the metaverse to promote communication and understanding among students from different cultural backgrounds (Gaurav, 2023; Li, 2022). Metaverse-based platforms can transcend geographical and cultural boundaries, providing students with a common virtual space where they can learn, communicate, and collaborate (Dwivedi et al., 2022). Exploration of how to design cross-cultural education projects and how to address challenges arising from cultural differences is crucial for building inclusive and diverse educational environments.

Teacher training and support

Teacher training and support emphasizes the provision of necessary resources and training for teachers to ensure they can effectively teach (Abonyi et al., 2020). As educational technology continues to evolve, teachers need to acquire new skills and knowledge to effectively utilize the metaverse for instructional design and implementation (Lee & Hwang, 2022; Sripan & Jeerapattanatorn, 2025). This includes training on technical operations of metaverse-based platforms, virtual classroom management, online interaction strategies, and cross-cultural communication. Additionally, further research is required to examine how sustained support and resources can be provided to enable teachers to effectively adapt to emerging educational technologies.

Continuous learning and career development

Continuous learning and professional development highlight how the metaverse supports vocational training and lifelong learning (AbuKhousa et al., 2023). With the constant changes in job requirements and rapid technological advancements, lifelong learning has become increasingly important (Drewery et al., 2020). The metaverse provides new opportunities for vocational skill updates and personal development by offering flexible learning pathways, simulated practice environments, and personalized learning experiences which require further investigation.

Based on the 10 themes in the second column in **Appendix C**, future research in the metaverse will be interdisciplinary and multidimensional, aiming to explore how the metaverse can support educational innovation and improve learning outcomes, while considering ethical, social, and cultural factors, towards realizing an inclusive, secure, and efficient global educational environment.

DISCUSSION

Since 2021, advancements in technology and shifts in educational needs have spurred a rapid increase in research on the metaverse in education. This area of exploration reached a peak in 2023, indicating not only the potential transformative impact of the metaverse in education but also reflecting the keen interest of the global academic and industrial communities in exploring innovative educational models. This review highlights the prominent position of East Asian and Middle Eastern countries in this field (Al-Adwan & Al-Debei, 2024; Faqih & Jaradat, 2021; Nam et al., 2024; Shen et al., 2022; Yang et al., 2022), showcasing the interest and development of the metaverse within Asian nations. Moreover, research from Europe and North America (Di Natale et al., 2024a; Lee & Chaney, 2024; Makransky & Mayer, 2022; Sin et al., 2023), though less in volume, underscores the global attention that the metaverse in education is garnering. This distribution of research might reflect the varying levels of acceptance, investment in educational technological innovation and different cultures or infrastructure across different regions, as well as research priorities in science and technology education among developed and developing countries.

Regarding research and analysis methodologies, the review revealed that surveys were the most common method, followed by interviews. The use of experiments, focus groups, grounded theory, quasi-experiments, and reflective journals was less frequent. PLS-SEM emerged as the primary analytical tool (Kalınkara & Özdemir, 2024; Kim & Lee, 2023), supplemented by regression analysis, thematic analysis, content analysis, sentiment analysis, case study analysis, ANN and ANFIS. These methodologies reveal the methodological innovation and diversity in the metaverse research, with researchers not only demonstrating creativity in data collection but also seeking advanced techniques suitable for their research questions and types of data. However, studies that combine different methods for data collection and analysis are still relatively scarce.

A comprehensive analysis of the metaverse domain reveals that while its exploration and application have received widespread attention globally, current research and practice remain concentrated primarily within the domain of general education (Shen et al., 2023). Exploration and application in specific disciplinary fields are still in the nascent stages (Dwivedi et al., 2022; Tlili et al., 2022). The potential of the metaverse has not been fully exploited, especially in the application to specific disciplines (Alfaisal et al., 2024), for example, English and mathematics. Future research should explore how the metaverse can be integrated into diverse disciplines by overcoming existing challenges and designing programs aligned with subject-specific characteristics and learner needs. Thus, more systematic and discipline-oriented research of the metaverse is essential in education.

College and university students are the most common target groups in studies on the metaverse, reflecting researchers' recognition of the potential for applying the metaverse within higher education. The widespread focus on this group may stem from characteristics of undergraduates such as their acceptance of technology, autonomy in learning, and willingness to explore emerging educational tools (Lai & Hong, 2015), making them ideal subjects for the metaverse research (Al-Adwan et al., 2023). However, we believe that more studies are required to examine the needs of students in specialized fields and students with disabilities, utilizing the advantages of the metaverse to help such students overcome learning barriers, and future research should also expand to other groups beyond university students, such as children and their parents (Bonales-Daimiel et al., 2024) to better understand their diverse experiences in the metaverse.

For models and theories in reviewed studies, it was found that TAM and UTAUT are widely used, highlighting the importance researchers place on understanding the motivations behind users' adoption and acceptance of emerging technologies (Al-Adwan & Al-Debei, 2024; Di Natale et al., 2024a). Moreover, by the application of EECM, PPM, flow theory, and DOI (Almarzouqi et al., 2022; Pal et al., 2023; Yang et al., 2024), researchers consider a broader range of psychological and social factors in exploring the acceptance and continued adoption of the metaverse in education. The limited use of RBV, SDT, CoI, and CLT highlights the need to integrate commonly adopted mature models with emerging perspectives to theorize holistically the potential of the metaverse in education.

The top 25 key influential factors were identified in **Table 2**, involving technology, individual psychology, and social factors (Lee & Chaney, 2024; Sediyaningsih et al., 2023; Shen et al., 2022). These factors are crucial to understanding and promoting the adoption of the metaverse in education. However, the literature lacks an exploration of the interactions between these factors, as well as research across cultural and disciplinary backgrounds. Cultural factors and technological infrastructure influencing the adoption of the metaverse in education require further research as well. Therefore, on one hand, educators need to comprehensively consider these diverse factors when designing and implementing metaverse-based projects to enhance student engagement and motivation. On the other hand, policymakers can formulate investment policies targeting metaverse-based infrastructure or develop training programs to improve both teachers' and students' understanding and application of the metaverse.

By combining traditional models with novel theories in **Appendix B** and the factors outlined in **Table 2**, this systematic review proposes a feasible theoretical framework outlined in **Figure 9**. These theories and models are frequently adopted in the literature and have been validated in various cultural contexts (Al-Adwan et al., 2023; Alkhwaldi, 2024; Almarzouqi et al., 2022; Pan et al., 2023). However, across different cultural contexts, the constructs of these theories and models may have different impacts on the adoption of emerging technologies. Therefore, it is necessary to examine these theories or models in various cultural contexts. To validate different models and theories, researchers need to explore the potential applications, challenges, and user attitudes or behavior patterns of the metaverse in education in the future.

CONCLUSION AND IMPLICATIONS

This systematic review has scrutinized the evolving landscape of the metaverse in education, uncovering trends, methodologies, target groups, theoretical frameworks, and influential factors that define the field. The metaverse research surge since 2021 underscores a global fascination with metaverse-based educational applications. Yet, the focus has predominantly been on general education, with some disciplines receiving less attention, indicating a need for more balanced research in specific disciplines. The use of research methods and theoretical models reveals the diversity and complexity of metaverse research. Surveys and interviews are the most common research methods, while TAM and the UTAUT are the most frequently applied as theoretical frameworks. These frameworks, which have been instrumental in identifying the current status of the metaverse adoption and the key factors influencing this process, suggest the need for further investigation into the dynamics among these factors to better leverage the metaverse for quality education.

While prior studies have explored the metaverse in fields such as medicine and engineering, there is still a lack of research in core subjects such as English and mathematics. In English education, immersive environments may enhance language and intercultural skills. In mathematics, 3D visualization and virtual experiments can support abstract thinking and spatial reasoning. However, challenges remain, including limited access to this technology, high costs, insufficient teacher training, and misaligned assessment methods. Therefore, it is essential for researchers to conduct more targeted designs and empirical studies based on specific pedagogical needs of different subject areas. Educators should align teaching strategies with the metaverse adoption factors identified in this review, including selecting appropriate platforms, fostering student engagement, and pursuing professional development in both technology use and pedagogical design. Additionally, policymakers should support interdisciplinary research and practice by providing flexible policies, targeted resources and funding. Investment in training, infrastructure, and context-specific guidance is essential to promote effective and scalable implementation of metaverse-based education in the future.

Limitations

This review illuminates the evolving landscape of the metaverse in education by providing some recommendations for practitioners. However, there are still some limitations. Firstly, this review only searched the Web of Science database which may have disregarded relevant literature from other databases, possibly resulting in a less comprehensive analysis. Secondly, although the selected publishers are all reputable academic publishers, this selection may lead to publication bias. These publishers often have high publication thresholds, potentially overlooking some important studies not published in these journals. Therefore, future scholars should expand the search scope to include other important databases, such as Scopus and Google Scholar for broader and comparative results.

Author contributions: XJY: conceptualization, methodology, data curation, formal analysis, writing – original draft, writing – review & editing; **GKSA:** supervision, formal analysis, writing – original draft, writing – review & editing; **ZJL:** formal analysis, data curation, writing – original draft; **OTH:** methodology, resources, writing – review & editing. All 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 systematic review does not involve human participants; therefore, ethical approval was not required.

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

Abonyi, U. K., Yeboah, R., & Luguterah, A. W. (2020). Exploring work environment factors influencing the application of teacher professional development in Ghanaian basic schools. *Cogent Social Sciences, 6*(1), Article 1778915. https://doi.org/10.1080/23311886.2020.1778915

AbuKhousa, E., El-Tahawy, M. S., & Atif, Y. (2023). Envisioning architecture of metaverse intensive learning experience (MiLEx): Career readiness in the 21st century and collective intelligence development scenario. *Future Internet, 15*(2), Article 53. https://doi.org/10.3390/fi15020053

Al-Adwan, A. S., & Al-Debei, M. M. (2024). The determinants of Gen Z's metaverse adoption decisions in higher education: Integrating UTAUT2 with personal innovativeness in IT. *Education and Information Technologies, 29*(6), 7413–7445. https://doi.org/10.1007/s10639-023-12080-1

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*(11), 15381–15413. https://doi.org/10.1007/s10639-023-11816-3

Alam, A., & Mohanty, A. (2022). Metaverse and posthuman animated avatars for teaching-learning process: Interperception in virtual universe for educational transformation. In M. Panda (Ed.), *Innovations in intelligent computing and communication. ICIICC 2022. Communications in computer and information science, vol 1737* (pp. 47–61). Springer. https://doi.org/10.1007/978-3-031-23233-6_4

AlDhanhani, B., Daradkeh, M., Gawanmeh, A., Atalla, S., & Miniaoui, S. (2023). Metaverse adoption in UAE higher education: A hybrid SEM-ANN approach. In *Proceedings of the 2023 International Conference on Intelligent Metaverse Technologies & Applications* (pp. 98–104). IEEE. https://doi.org/10.1109/iMETA59369.2023.10294928

Alfaisal, R., Hashim, H., & Azizan, U. H. (2024). Metaverse system adoption in education: A systematic literature review. *Journal of Computers in Education, 11*(1), 259–303. https://doi.org/10.1007/s40692-022-00256-6

Alhalaybeh, A., & Althunibat, A. (2023). Measuring acceptance of adoption metaverse in E-learning by using TAM model. In *Proceedings of the 2023 International Conference on Information Technology* (pp. 361–366). IEEE. https://doi.org/10.1109/ICIT58056.2023.10226171

Alkhwaldi, A. F. (2024). Understanding learners' intention toward Metaverse in higher education institutions from a developing country perspective: UTAUT and ISS integrated model. *Kybernetes, 53*(12), 6008–6035. https://doi.org/10.1108/K-03-2023-0459

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*, 43421–43434. https://doi.org/10.1109/ACCESS.2022.3169285

Arpaci, I., & Bahari, M. (2024). Investigating the role of psychological needs in predicting the educational sustainability of Metaverse using a deep learning-based hybrid SEM-ANN technique. *Interactive Learning Environments, 32*(6), 2957–2969. https://doi.org/10.1080/10494820.2022.2164313

Baker, J., Nam, K., & Dutt, C. S. (2023). A user experience perspective on heritage tourism in the metaverse: Empirical evidence and design dilemmas for VR. *Information Technology & Tourism, 25*(3), 265–306. https://doi.org/10.1007/s40558-023-00256-x

Beck, D., Morgado, L., & O'Shea, P. (2024). Educational practices and strategies with immersive learning environments: Mapping of reviews for using the metaverse. *IEEE Transactions on Learning Technologies, 17*, 319–341. https://doi.org/10.1109/TLT.2023.3243946

Bojic, L. (2022). Metaverse through the prism of power and addiction: What will happen when the virtual world becomes more attractive than reality? *European Journal of Futures Research, 10*(1), Article 22. https://doi.org/10.1186/s40309-022-00208-4

Bonales-Daimiel, G., Moreno-Albarracín, B., & García-Rivero, A. (2024). Children's behavior at metaverses: Interactions, digital identities, and parent's perceptions. *Online Journal of Communication and Media Technologies, 14*(2), Article e202418. https://doi.org/10.30935/ojcmt/14338

Cassidy, L. C., Leenaars, C. H. C., Rincon, A. V., & Pfefferle, D. (2021). Comprehensive search filters for retrieving publications on nonhuman primates for literature reviews (filterNHP). *American Journal of Primatology, 83*(7), Article e23287. https://doi.org/10.1002/ajp.23287

Chaipidech, P., Kajonmanee, T., Chaipah, K., Panjaburee, P., & Srisawasdi, N. (2021). Implementation of an andragogical teacher professional development training program for boosting TPACK in STEM education: The essential role of a personalized learning system. *Educational Technology & Society, 24*(4), 220–239.

Chanda, R. S., Pabalkar, V. R., & Sharma, S. (2024). Attitude and behavioral intention for using metaverse in education: Learner's perspective. *Journal of Applied Research in Higher Education, 16*(5), 2168–2184. https://doi.org/10.1108/JARHE-07-2023-0307

Chen, H. J. (2024). Gather in the metaverse: Learning outcomes, virtual presence, and perceptions of high-and low-achieving pre-service teachers of English as a foreign language. *Education and Information Technologies, 29*(7), 8549–8577. https://doi.org/10.1007/s10639-023-12135-3

Chen, W., Zhang, J., & Yu, Z. (2023a). A bibliometric analysis of the use of the metaverse in education over three decades. *International Journal of Information and Communication Technology Education, 19*(1), 1–16. https://doi.org/10.4018/IJICTE.322101

Chen, X., Zou, D., Xie, H., & Wang, F. L. (2023b). 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

Chen, Z. (2022). Exploring the application scenarios and issues facing Metaverse technology in education. *Interactive Learning Environments, 32*(5), 1975–1987. https://doi.org/10.1080/10494820.2022.2133148

Choi, H., & Kim, S. (2017). A content service deployment plan for metaverse museum exhibitions–Centering on the combination of beacons and HMDs. *International Journal of Information Management, 37*(1), 1519–1527. https://doi.org/10.1016/j.ijinfomgt.2016.04.017

Chua, H. W., & Yu, Z. (2024). A systematic literature review of the acceptability of the use of Metaverse in education over 16 years. *Journal of Computers in Education, 11*(2), 615–665. https://doi.org/10.1007/s40692-023-00273-z

Di Natale, A. F., Bartolotta, S., Gaggioli, A., Riva, G., & Villani, D. (2024a). Exploring students' acceptance and continuance intention in using immersive virtual reality and metaverse integrated learning environments: The case of an Italian university course. *Education and Information Technologies, 29*(12), 14749–14768. https://doi.org/10.1007/s10639-023-12436-7

Di Natale, A. F., Repetto, C., Costantini, G., Riva, G., Bricolo, E., & Villani, D. (2024b). Learning in the Metaverse: Are university students willing to learn in immersive virtual reality? *Cyberpsychology, Behavior, and Social Networking, 27*(1), 28–36. https://doi.org/10.1089/cyber.2022.0395

Di Pietro, R., & Cresci, S. (2021). Metaverse: Security and privacy issues. In *Proceedings of the 2021 3rd IEEE International Conference on Trust, Privacy and Security in Intelligent Systems and Applications* (pp. 281–288). IEEE. https://doi.org/10.1109/TPSISA52974.2021.00032

Drewery, D. W., Sproule, R., & Pretti, T. J. (2020). Lifelong learning mindset and career success: Evidence from the field of accounting and finance. *Higher Education, Skills and Work-Based Learning, 10*(3), 567–580. https://doi.org/10.1108/HESWBL-03-2019-0041

Dwivedi, Y. K., Hughes, L., Baabdullah, A. M., Ribeiro-Navarrete, S., Giannakis, M., Al-Debei, M. M., Dennehy, D., Metri, B., Buhalis, D., Cheung, C. M. K., Conboy, K., Doyle, R., Dubey, R., Dutot, V., Felix, R., Goyal, D. P., Gustafsson, A., Hinsch, C., Jebabli, I., … Wamba, S. F. (2022). Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International Journal of Information Management, 66*, Article 102542. https://doi.org/10.1016/j.ijinfomgt.2022.102542

Estudante, A., & Dietrich, N. (2020). Using augmented reality to stimulate students and diffuse escape game activities to larger audiences. *Journal of Chemical Education, 97*(5), 1368–1374. https://doi.org/10.1021/acs.jchemed.9b00933

Faqih, K. M. S., & Jaradat, M. I. R. M. (2021). Integrating TTF and UTAUT2 theories to investigate the adoption of augmented reality technology in education: Perspective from a developing country. *Technology in Society, 67*, Article 101787. https://doi.org/10.1016/j.techsoc.2021.101787

Feng, X., Wang, X., & Su, Y. (2024). An analysis of the current status of metaverse research based on bibliometrics. *Library Hi Tech, 42*(1), 284–308. https://doi.org/10.1108/LHT-10-2022-0467

Gaurav, A. (2023). Metaverse and globalization: Cultural exchange and digital diplomacy. *Data Science Insights Magazine, 5*, 23–27.

Hadi Mogavi, R., Hoffman, J., Deng, C., Du, Y., Haq, E.-U., & Hui, P. (2023). Envisioning an inclusive metaverse: Student perspectives on accessible and empowering metaverse-enabled learning. In *Proceedings of the 10th ACM Conference on Learning @ SCALE* (pp. 346–353). ACM. https://doi.org/10.1145/3573051.3596185

Han, Z., Tu, Y., & Huang, C. (2023). A framework for constructing a technology-enhanced education metaverse: Learner engagement with human-machine collaboration. *IEEE Transactions on Learning Technologies, 16*(6), 1179–1189. https://doi.org/10.1109/TLT.2023.3257511

Hare, R., & Tang, Y. (2022). Hierarchical deep reinforcement learning with experience sharing for metaverse in education. *IEEE Transactions on Systems, Man, and Cybernetics: Systems, 53*(4), 2047–2055. https://doi.org/10.1109/TSMC.2022.3227919

Hsieh, T. L. (2014). Motivation matters? The relationship among different types of learning motivation, engagement behaviors and learning outcomes of undergraduate students in Taiwan. *Higher Education, 68*(3), 417–433. https://doi.org/10.1007/s10734-014-9720-6

Huang, C. L., Luo, Y. F., Yang, S. C., Lu, C. M., & Chen, A. S. (2020). Influence of students' learning style, sense of presence, and cognitive load on learning outcomes in an immersive virtual reality learning environment. *Journal of Educational Computing Research, 58*(3), 596–615. https://doi.org/10.1177/0735633119867422

Hwang, G. J., Tu, Y. F., & Chu, H. C. (2023a). Conceptions of the metaverse in higher education: A draw-a-picture analysis and surveys to investigate the perceptions of students with different motivation levels. *Computers & Education, 203*, Article 104868. https://doi.org/10.1016/j.compedu.2023.104868

Hwang, Y. (2023). When makers meet the metaverse: Effects of creating NFT metaverse exhibition in maker education. *Computers & Education, 194*, Article 104693. https://doi.org/10.1016/j.compedu.2022.104693

Hwang, Y., Shin, D., & Lee, H. (2023b). Students' perception on immersive learning through 2D and 3D metaverse platforms. *Educational Technology Research and Development, 71*(4), 1687–1708. https://doi.org/10.1007/s11423-023-10238-9

İbili, E., Ölmez, M., Cihan, A., Bilal, F., İbili, A. B., Okumus, N., & Billinghurst, M. (2023). Investigation of learners' behavioral intentions to use metaverse learning environment in higher education: A virtual computer laboratory. *Interactive Learning Environments, 32*(10), 5893–5918. https://doi.org/10.1080/10494820.2023.2240860

Jagatheesaperumal, S. K., Ahmad, K., Al-Fuqaha, A., & Qadir, J. (2024). 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

Jonsson, B., & Tarski, A. (1951). Boolean algebras with operators. Part I. *American Journal of Mathematics, 73*(4), 891–939. https://doi.org/10.2307/2372123

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

Kalınkara, Y., & Özdemir, O. (2024). Anatomy in the metaverse: Exploring student technology acceptance through the UTAUT2 model. *Anatomical Sciences Education, 17*(2), 319–336. https://doi.org/10.1002/ase.2353

Kaputa, V., Loučanová, E., & Tejerina-Gaite, F. A. (2022). Digital transformation in higher education institutions as a driver of social oriented innovations. In C. Păunescu, K. L. Lepik, & N. Spencer (Eds.), *Social innovation in higher education: Landscape, practices, and opportunities* (pp. 61–85). Springer. https://doi.org/10.1007/978-3-030-84044-0_4

Kim, H., & Lee, H. (2023). Performing arts metaverse: The effect of perceived distance and subjective experience. *Computers in Human Behavior, 146*, Article 107827. https://doi.org/10.1016/j.chb.2023.107827

Kim, Y., & Kim, M. Y. (2023). Effects of metaverse-based career mentoring for nursing students: A mixed methods study. *BMC Nursing, 22*(1), Article 160. https://doi.org/10.1186/s12912-023-01323-8

Lai, K., & Hong, K. (2015). Technology use and learning characteristics of students in higher education: Do generational differences exist? *British Journal of Educational Technology, 46*(4), 725–738. https://doi.org/10.1111/bjet.12161

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, H., Yi, Y., Moon, W., & Yeo, J. Y. (2023). Exploring the potential use of the metaverse in nurse education through a mock trial. *Nurse Education Today, 131*, Article 105974. https://doi.org/10.1016/j.nedt.2023.105974

Lee, M. S. W., & Chaney, D. (2024). The psychological and functional factors driving metaverse resistance. *Internet Research, 34*(1), 195–215. https://doi.org/10.1108/INTR-08-2022-0647

Lee, N., & Jo, M. (2023). Exploring problem-based learning curricula in the metaverse: The hospitality students' perspective. *Journal of Hospitality, Leisure, Sport & Tourism Education, 32*, Article 100427. https://doi.org/10.1016/j.jhlste.2023.100427

Li, H., Cui, C., & Jiang, S. (2024). Strategy for improving the football teaching quality by AI and metaverse-empowered in mobile internet environment. *Wireless Networks, 30*(5), 4343–4352. https://doi.org/10.1007/s11276-022-03000-1

Li, J. (2022). Impact of Metaverse cultural communication on the mental health of international students in China: Highlighting effects of healthcare anxiety and cyberchondria. *American Journal of Health Behavior, 46*(6), 809–820. https://doi.org/10.5993/AJHB.46.6.21

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. In *Proceedings of the 2022 IEEE International Conference on Big Data* (pp. 2857–2866). https://doi.org/10.1109/BigData55660.2022.10021004

Makransky, G., & Mayer, R. E. (2022). Benefits of taking a virtual field trip in immersive virtual reality: Evidence for the immersion principle in multimedia learning. *Educational Psychology Review, 34*(3), 1771–1798. https://doi.org/10.1007/s10648-022-09675-4

Nam, K., Baker, J., & Dutt, C. S. (2024). Does familiarity with the attraction matter? Antecedents of satisfaction with virtual reality for heritage tourism. *Information Technology & Tourism, 26*(1), 25–57. https://doi.org/10.1007/s40558-023-00273-w

Oh, Y. K., Yi, J., & Kim, J. (2024). What enhances or worsens the user-generated metaverse experience? An application of BERTopic to Roblox user eWOM. *Internet Research, 34*(5), 1800–1817. https://doi.org/10.1108/INTR-03-2022-0178

Onu, P., Pradhan, A., & Mbohwa, C. (2024). Potential to use metaverse for future teaching and learning. *Education and Information Technologies, 29*(7), 8893–8924. https://doi.org/10.1007/s10639-023-12167-9

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *International Journal of Surgery, 88*, Article 105906. https://doi.org/10.1016/j.ijsu.2021.105906

Pal, D., Zhang, X., Mukherjee, S., & Funilkul, S. (2023). Switching to metaverse? Perspectives from push-pull-mooring model. *Journal of Computers in Education, 12*(1), 1–35. https://doi.org/10.1007/s40692-023-00301-y

Pan, S., Jung, S., & Suo, S. (2023). Understanding the adoption and usage behaviors of popular and emerging metaverse platforms: A study based on the extended technology acceptance model. *Journal of Broadcasting & Electronic Media, 67(4*), 574–595. https://doi.org/10.1080/08838151.2023.2224477

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

Park, S.-M., & Kim, Y.-G. (2022b). A Metaverse: Taxonomy, components, applications, and open challenges. *IEEE Access, 10*, 4209–4251. https://doi.org/10.1109/ACCESS.2021.3140175

Parmaxi, A. (2023). Virtual reality in language learning: A systematic review and implications for research and practice. *Interactive Learning Environments, 31*(1), 172–184. https://doi.org/10.1080/10494820.2020.1765392

Pérez, J., Díaz, J., Garcia-Martin, J., & Tabuenca, B. (2020). Systematic literature reviews in software engineering–Enhancement of the study selection process using Cohen's kappa statistic. *Journal of Systems and Software, 168*, Article 110657. https://doi.org/10.1016/j.jss.2020.110657

Potkonjak, V., Gardner, M., Callaghan, V., Mattila, P., Guetl, C., Petrović, V. M., & Jovanović, K. (2016). Virtual laboratories for education in science, technology, and engineering: A review. *Computers & Education, 95*, 309–327. https://doi.org/10.1016/j.compedu.2016.02.002

Ren, L., Yang, F., Gu, C., Sun, J., & Liu, Y. (2022). A study of factors influencing Chinese college students' intention of using metaverse technology for basketball learning: Extending the technology acceptance model. *Frontiers in Psychology, 13*. https://doi.org/10.3389/fpsyg.2022.1049972

Roy, R., Babakerkhell, M. D., Mukherjee, S., Pal, D., & Funilkul, S. (2023). Development of a framework for metaverse in education: A systematic literature review approach. *IEEE Access, 11*, 57717–57734. https://doi.org/10.1109/ACCESS.2023.3283273

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

Saritas, M. T., & Topraklikoglu, K. (2022). Systematic literature review on the use of metaverse in education. *International Journal of Technology in Education, 5*(4), 586–607. https://doi.org/10.46328/ijte.319

Sediyaningsih, S., Ristiyono, M. P., Launggu, K., & Ochieng Juma, P. (2023). De-contextual communication: Factors influencing usage intentions of metaverse technology in digital library services. *Heliyon, 9*(10), Article e20388. https://doi.org/10.1016/j.heliyon.2023.e20388

Shen, J., Zhou, X., Wu, W., Wang, L., & Chen, Z. (2023). Worldwide overview and country differences in metaverse research: A bibliometric analysis. *Sustainability, 15*(4), Article 3541. https://doi.org/10.3390/su15043541

Shen, S., Xu, K., Sotiriadis, M., & Wang, Y. (2022). Exploring the factors influencing the adoption and usage of augmented reality and virtual reality applications in tourism education within the context of COVID-19 pandemic. *Journal of Hospitality, Leisure, Sport & Tourism Education, 30*, Article 100373. https://doi.org/10.1016/j.jhlste.2022.100373

Shu, X., & Gu, X. (2023). An empirical study of a smart education model enabled by the Edu-Metaverse to enhance better learning outcomes for students. *Systems, 11*(2), Article 75. https://doi.org/10.3390/systems11020075

Sin, Z. P., Jia, Y., Wu, A. C., Zhao, I. D., Li, R. C., Ng, P. H., Huang, X., Baciu, G., Cao, J., & Li, Q. (2023). Towards an edu-metaverse of knowledge: Immersive exploration of university courses. *IEEE Transactions on Learning Technologies, 16*(6), 1096–1110. https://doi.org/10.1109/TLT.2023.3290814

Singla, A., Gupta, N., Aeron, P., Jain, A., Garg, R., Sharma, D., Gupta, B. B., & Arya, V. (2023). Building the metaverse: Design considerations, socio-technical elements, and future research directions of metaverse. *Journal of Global Information Management, 31*(2), 1–28. https://doi.org/10.4018/JGIM.321755

Siyaev, A., & Jo, G. S. (2021). Neuro-symbolic speech understanding in aircraft maintenance metaverse. *IEEE Access, 9*, 154484–154499. https://doi.org/10.1109/ACCESS.2021.3128616

Song, Y., Cao, J., Wu, K., Yu, P. L. H., & Lee, J. C. K. (2023). Developing 'Learningverse'–A 3D metaverse platform to support teaching, social and cognitive presences. *IEEE Transactions on Learning Technologies, 16*(6), 1165–1178. https://doi.org/10.1109/TLT.2023.3276574

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

Tlili, A., Huang, R., Shehata, B., Liu, D., Zhao, J., Metwally, A. H. S., Wang, H., Denden, M., Bozkurt, A., Lee, L. H., Beyoglu, D., Altinay, F., Sharma, R. C., Altinay, Z., Li, Z., Liu, J., Ahmad, F., Hu, Y., Salha, S., ... Burgos, D. (2022). Is metaverse in education a blessing or a curse: A combined content and bibliometric analysis. *Smart Learning Environments, 9*(1), Article 24. https://doi.org/10.1186/s40561-022-00205-x

Villalonga-Gómez, C., Ortega-Fernández, E., & Borau-Boira, E. (2023). Fifteen years of metaverse in higher education: A systematic literature review. *IEEE Transactions on Learning Technologies, 16*(6), 1057–1070. https://doi.org/10.1109/TLT.2023.3302382

Wang, K., Li, B., Tian, T., Zakuan, N., & Rani, P. (2023a). Evaluate the drivers for digital transformation in higher education institutions in the era of industry 4.0 based on decision-making method. *Journal of Innovation & Knowledge, 8*(3), Article 100364. https://doi.org/10.1016/j.jik.2023.100364

Wang, M., Yu, H., Bell, Z., & Chu, X. (2022). Constructing an edu-metaverse ecosystem: A new and innovative framework. *IEEE Transactions on Learning Technologies, 15*(6), 685–696. https://doi.org/10.1109/TLT.2022.3210828

Wang, Y., Su, Z., Zhang, N., Xing, R., Liu, D., Luan, T. H., & Shen, X. (2023b). A survey on metaverse: Fundamentals, security, and privacy. *IEEE Communications Surveys & Tutorials, 25*(1), 319–352. https://doi.org/10.1109/COMST.2022.3202047

Wiangkham, A., & Vongvit, R. (2024). Exploring the drivers for the adoption of metaverse technology in engineering education using PLS-SEM and ANFIS. *Education and Information Technologies, 29*(6), 7385–7412 https://doi.org/10.1007/s10639-023-12127-3

Wolfswinkel, J. F., Furtmueller, E., & Wilderom, C. P. M. (2013). Using grounded theory as a method for rigorously reviewing literature. *European Journal of Information Systems, 22*(1), 45–55. https://doi.org/10.1057/ejis.2011.51

Wu, J. G., Zhang, D., & Lee, S. M. (2023). Into the brave new metaverse: Envisaging future language teaching and learning. *IEEE Transactions on Learning Technologies, 17*, 44–53. https://doi.org/10.1109/TLT.2023.3259470

Wu, R., & Yu, Z. (2024). Investigating users' acceptance of the metaverse with an extended technology acceptance model. *International Journal of Human-Computer Interaction, 40*(19), 5810–5826. https://doi.org/10.1080/10447318.2023.2241295

Xu, W., Zhang, N., & Wang, M. (2024). The impact of interaction on continuous use in online learning platforms: A metaverse perspective. *Internet Research, 34*(1), 79–106. https://doi.org/10.1108/INTR-08-2022-0600

Yang, F., Ren, L., & Gu, C. (2022). A study of college students' intention to use metaverse technology for basketball learning based on UTAUT2. *Heliyon, 8*(9), Article e10562. https://doi.org/10.1016/j.heliyon.2022.e10562

Yang, X., Cheng, P. Y., Liu, X., & Shih, S. P. (2024). The impact of immersive virtual reality on art education: A study of flow state, cognitive load, brain state, and motivation. *Education and Information Technologies, 29*(5), 6087–6106. https://doi.org/10.1007/s10639-023-12041-8

Yilmaz, M., O'Farrell, E., & Clarke, P. (2023). Examining the training and education potential of the metaverse: Results from an empirical study of next generation SAFe training. *Journal of Software: Evolution and Process, 35*(9), Article e2531. https://doi.org/10.1002/smr.2531

Yu, D. (2023). AI-empowered metaverse learning simulation technology application. In *Proceedings of the 2023 International Conference on Intelligent Metaverse Technologies & Applications* (pp. 1–6). IEEE. https://doi.org/10.1109/iMETA59369.2023.10294830

Zhang, X., Chen, Y., Hu, L., & Wang, Y. (2022). The metaverse in education: Definition, framework, features, potential applications, challenges, and future research topics. *Frontiers in Psychology, 13*. https://doi.org/10.3389/fpsyg.2022.1016300

Zheng, W., Yan, L., Zhang, W., Ouyang, L., & Wen, D. (2022). D→K→I: Data-Knowledge-Driven group intelligence framework for smart service in education metaverse. *IEEE Transactions on Systems, Man, and Cybernetics: Systems, 53*(4), 2056–2061. https://doi.org/10.1109/TSMC.2022.3228849

APPENDIX A

Table A1. Summary of the most recent related reviews (2022–2024)

Author(s)	Topic	Duration covered	Analyzed dimensions	Research gaps
Tlili et al. (2022)	A blessing or a curse of the metaverse in education	2007-2021	(a) Publication year, literature type, country, keywords, and research methods; (b) Types of metaverse used in education; (c) Disciplinary areas, student levels, and learning scenarios in the metaverse; (d) Students' digital identities and technologies used; (e) Evolution of the metaverse in education for generations X-Z; (f) Impact and challenges of the metaverse in education	Requires research on the evaluation of the effectiveness and impact of metaverse applications in education
Saritas and Topraklikoglu (2022)	The use of the metaverse in education	2004-2022	(a) Characteristics and trends of related research; (b) Literature years, countries, research types (exploratory, descriptive, explanatory research); (c) Distribution of education levels and technologies used	Requires research on in-depth case studies to involve the specific applications of metaverse technology in education
Li and Yu (2023)	The metaverse-based blended English learning	2008-2022	(a) Whether the metaverse can promote the engagement of English learners; (b) Whether immersive environments can enhance English learning outcomes; (c) Building digital literacy as the foundation for metaverse-based English learning; (d) Challenges of metaverse platforms	Requires more research on the application of the metaverse in English education
Chen et al. (2023b)	Metaverse in education: Contributors, cooperation, and themes	2004-2022	(a) Countries, institutions, and regions with the most research in the field; (b) Cooperation between countries and institutions; (c) Emerging research themes; (d) Journal articles based on Q1, disciplinary areas, and impact on students	Requires research on strategies for effectively integrating metaverse technology into curriculum design
Parmaxi (2023)	Virtual reality in language learning	2015-2018	(a) VR technology use, language learning environments, and duration of educational activities; (b) Strategies and languages used by learners in these virtual worlds	Requires research on learners' strategies and language use in virtual worlds
Roy et al. (2023)	Development of a framework for metaverse in education	2012- 2023	(a) Analysis includes publication trends; (b) Various applications related to the metaverse (language learning, science education, manufacturing training, etc.); (c) The impact on students and educational practices	Requires more theoretical research on the adoption and application of the metaverse in education
Villalonga-Gómez et al. (2023)	Metaverse in higher education	2000-2021	Technology, teaching, and content	Requires an in-depth study on educational models and learning experiences in the metaverse
Alfaisal et al. (2024)	Metaverse system adoption in education	2011-2022	(a) Publication years; (b) Major research areas of virtual universe systems; (c) Research methods; (d) Education levels (e.g., higher education, high school, primary school), schools; (e) Region; (f) Databases	Requires research on specific factors and challenges in the adoption of metaverse systems at certain educational levels
Chua and Yu (2024)	The acceptance and use of the metaverse in education	2008-2022	(a) Trends in the types of metaverse in the education field, shifting from a single metaverse platform or software to a more diverse combination of software and devices; (b) The importance of perceived usefulness and perceived ease of use for the acceptance and rejection of metaverse use in education	Requires research on acceptance and willingness to use metaverse systems among teachers and students
Jagatheesaperumal et al. (2024)	Extended reality and the metaverse	2010-2023	(a) Analysis includes metaverse applications (online classrooms, industrial training, aviation, maritime, military, and gaming) and supporting technologies, emphasizing ethical issues	Requires research on the application of the metaverse in different disciplinary fields

APPENDIX B

Table B1. Models and theories used with their respective application contexts and relevance

Models and theories used	Frequency and included studies	Application contexts	Relevance
TAM	8 (Al-Adwan et al., 2023; Alhalaybeh & Althunibat, 2023; Almarzouqi et al., 2022; İbili et al., 2023; Pan et al., 2023; Shen et al., 2022; Wu & Yu, 2024; Xu et al., 2024)	Applied in diverse educational settings, including immersive virtual labs, metaverse-based LMS, AR/VR-supported tourism education, and online learning for university and K-12 students in Jordan, China, Turkey, UAE, and South Korea; Used to evaluate adoption, continuous use, and platform preference	• Explaining initial user acceptance of the metaverse • Frequently extended to incorporate contextual factors such as enjoyment, social interaction, hedonic motivation, and innovativeness •PU and PEU remain central predictors, while added constructs enhance predictive power across different metaverse learning environments
UTAUT	5 (Alkhwaldi, 2024; Di Natale, Bartolotta, et al., 2024; Sediyaningsih et al., 2023; Wiangkham & Vongvit, 2024; Xu et al., 2024)	Applied in higher education, digital library systems, engineering education, and K12 online learning; contexts include university staff and students in Indonesia and Hungary (library services), engineering students in Thailand, university students in Jordan, and K12 students in China; explored both initial adoption and continuous use of the metaverse	•Captured social, technical, and behavioral factors influencing the acceptance of the metaverse • Common constructs include PE, EE, SI, FC • Integrated with models as TTF or ISS to improve contextual fit
Experiential learning theory	4 (Hwang et al., 2023b; Lee & Jo, 2023; Lee et al., 2023; Yilmaz et al., 2023)	Applied in university-level education in South Korea and Turkey involving immersive metaverse platforms for online learning (Ifland, Gather Town, Frame VR), mock trial simulations in nurse education (VRChat), problem-based learning in hospitality education and serious game-based training in engineering education (PlaySAFe)	•Interpreted how students learned through direct experience with metaverse platforms • Emphasized learning as a process involving concrete experience, reflective observation, abstract conceptualization, and active experimentation, represented in the students' engagement with different virtual environments
Extended UTAUT 2	3 (Al-Adwan & Al-Debei, 2024; Kalınkara & Özdemir, 2024; Yang et al., 2022)	Applied in higher education and specialized fields such as anatomy education and basketball education; research conducted among Gen Z university students in Jordan, first-year students in Turkey, and college athletes in China; focused on immersive learning, Eduniverse, and metaverse-based training	• Expanded traditional constructs with hedonic motivation, habit, behavioral intention, and personal innovativeness • Provided high explanatory power for behavioral intention and usage behavior • Useful for tailoring strategies in immersive, game-based, and informal learning environments
General extended TAM (ETAM)	3 (İbili et al., 2023; Pan et al., 2023; Wu & Yu, 2024)	Applied in a study examining undergraduate students' adoption of metaverse-based computer hardware learning	•Extended TAM by integrating additional factors, such as natural interaction, hedonic motivation, computer anxiety, and self-efficacy •Enriched framework helps better capture student behaviors in immersive metaverse-based learning. •Provided actionable insights for designing metaverse-based teaching systems in higher education
Cognitive affective model of immersive learning (CAMIL)	3 (Makransky & Mayer, 2022; Yu, 2023; Zheng et al., 2022)	Applied in immersive educational settings involving virtual field trips, personalized simulation learning environments, and intelligent learning systems within metaverse-based smart education for middle school and general education students	• Provided a framework to understand how immersion influences learning through cognitive and affective processes • Highlighted the model's value in explaining how emotional engagement enhances presence, retention, and long-term learning
Uses and gratifications theory	3 (Baker et al., 2023; Nam et al., 2024; Oh et al., 2024)	Used in a metaverse satisfaction study based on Roblox; analyzed user-generated content through BERTopic modeling to understand user motivations and risk perceptions	•Explained how users derive satisfaction from gratifications such as entertainment, escapism, social interaction, and avatar-based self-expression •Provided a theoretical lens to examine the dynamic interplay between user needs and perceived risks •Helped distinguish the metaverse from traditional digital media by emphasizing user-created content and experience-driven motivations

Table B1 (Continued).

Models and theories used	Frequency and included studies	Application contexts	Relevance
Diffusion of innovation (DOI)	2 (Almarzouqi et al., 2022; Pan et al., 2023)	Applied in metaverse-based education for medical and general higher education; studies included university students from the UAE and participants from China and South Korea, focusing on adoption intention and usage behavior across emerging and popular metaverse platforms	• Explained adoption decisions based on innovation characteristics such as perceived compatibility, observability, trialability, and relative advantage • Frequently integrated with TAM or SDT to enhance explanatory power • Helped distinguish between adoption of new platforms and continued use of existing ones
Task technology fit (TTF)	2 (Faqih & Jaradat, 2021; Sediyaningsih et al., 2023)	Applied in digital library services and augmented reality-based learning in the metaverse; participants included university staff in Indonesia and Hungary, and undergraduates in Jordan	•Assessed the alignment between technological features and user tasks • Frequently integrated with UTAUT or ISS models • Perceived fit between task needs and tech features significantly influenced intention to adopt the metaverse or AR tools in education
Social cognitive theory (SCT)	2 (Hwang et al., 2023a; Kim & Kim, 2023)	Applied in studies of South Korean and Taiwan, evaluating a metaverse-based career mentoring program for nursing students and mentors	•Provided a theoretical basis to understand how immersive metaverse environments enhance learners' self-efficacy through social presence, emotional engagement, and mentor feedback • Helped interpret changes in students' confidence, communication behavior, and perceived realism, supporting metaverse-based design for career development
Flow theory	2 (Wu & Yu, 2024; Yang et al., 2024)	Applied involving college students in an art education context in China	• Explained the enhanced focus, engagement, and motivation • Validated immersive activities in the metaverse promoted higher levels of attention and art appreciation
Situated learning theory	2 (Hwang et al., 2023b; Siyaev & Jo, 2021)	Utilized in a South Korean study focusing on context-rich learning environments within metaverse-based platforms for university students	•Interpreted how learning is embedded in authentic social and cultural contexts •Students' learning was situated within the virtual communities and interactive spaces of metaverse-based platforms, where social presence and contextual cues contributed to deeper engagement and the development of shared meaning among learners
Constructivism theory	2 (Hwang, 2023; Sin et al., 2023)	Applied in metaverse-supported maker education and immersive course design environments among university students	• Highlighted how learners build knowledge through hands-on exploration and social interaction •Explained how immersive environments facilitate cognitive engagement, ownership, and creative learning • Supported learner-centered designs by framing virtual exhibitions, knowledge mapping, and participatory learning as authentic opportunities for students to actively construct meaning in digital education spaces
Expectation-confirmation model (ECM)	1 (Di Natale et al., 2024a)	Applied in an Italian university course integrating immersive virtual reality (IVR) and metaverse applications; focused on university students' pre- and post-adoption perceptions in educational settings	•Used to bridge pre-adoption expectations and post-usage satisfaction •Confirmed initial expectations influenced perceived usefulness, satisfaction, and confidence which enhanced students' continued intention to use the metaverse in learning environments
Push-pull-mooring (PPM)	1 (Pal et al., 2023)	Applied in a cross-cultural study involving university students from India and Thailand; Investigated switching intentions from traditional to metaverse-based education using a novel framework combining virtual place attachment, symbolic threat, and migration theory	•Provided insights into learners' motivation to switch from physical to virtual learning spaces • Virtual place attachment emerged as a key pull factor, while dissatisfaction and perceived boredom were major push factors • Highlighted the role of immersive virtual identity in metaverse education beyond traditional acceptance models

Table B1 (Continued).

Models and theories used	Frequency and included studies	Application contexts	Relevance
Resource-based view (RBV)	1 (AlDhanhani et al., 2023)	Applied in UAE higher education institutions to assess organizational and technological readiness for adopting the metaverse; participants included faculty and administrative personnel	•Examined how institutional resources, such as IT infrastructure, technical skills, financial readiness, and staff capabilities contribute to the metaverse implementation • Framed the metaverse readiness as a function of valuable, rare, inimitable, and organizationally embedded resources •Emphasized the importance of leveraging existing assets to achieve sustainable digital transformation
Dynamic capabilities theory	1 (AlDhanhani et al., 2023)	Applied in UAE higher education institutions to examine institutional readiness for the metaverse adoption; target participants included faculty and administrative staff engaged in digital transformation	• Used to evaluate how institutions adapt, integrate, and reconfigure internal resources in response to technological change •Emphasized strategic agility, including IT infrastructure, staff capabilities, and management support, as critical for successful metaverse integration • Highlighted the metaverse as a dynamic shift requiring more than static resources
ADKAR model	1 (AlDhanhani et al., 2023)	Used alongside RBV and dynamic capabilities theory to assess readiness for the metaverse adoption in UAE higher education	• Focused on five stages: awareness, desire, knowledge, ability, and reinforcement, helping to map how faculty and institutions transition toward the metaverse integration •By highlighting human and managerial dimensions, ADKAR complements the technological/infrastructural focus on RBV and DCT • Emphasized the psychological and procedural readiness for sustainable innovation in academic settings
Community of inquiry (CoI) framework	1 (Song et al., 2023)	Exploring immersive learning in a custom-designed metaverse platform called "Learningverse"; targeted postgraduatesengaged in 3D educational environments	• Assessed students' perceived teaching presence, social presence, and cognitive presence in an immersive metaverse •Enabled evaluation of interaction quality, engagement, and collaboration among students
Perceived risk theory	1 (Oh et al., 2024)	Analyzed user-generated metaverse experience on Roblox using text mining and sentiment analysis of user reviews	• Explored user concerns regarding safety, identity threats, and emotional risks within the metaverse •Enabled analysis of how these perceived risks influenced satisfaction with user-generated content • By integrating with other theories, it provided a dual framework to understand how risk perceptions affect the metaverse adoption, user trust, and sustained engagement
Embodied cognition and humanism theories	1 (Han et al., 2023)	Applied in a conceptual framework for the "Edu-Metaverse" to enhance learner engagement through human–machine interaction	•Guided the development of an educational metaverse that supports embodied engagement (via avatars, presence, physical interaction metaphors) and humanistic principles (respect for learner agency, creativity, and holistic development) • Justified the focus on interactive, presence-rich learning with emotional and social resonance
REEPS framework (recognition, empowerment, engagement, privacy, safety)	1 (Hadi Mogavi et al., 2023)	Applied in a cross-national qualitative study (USA and Hong Kong) focusing on university students with disabilities and their expectations for future metaverse-based learning	•Provided a holistic model to synthesize students' concerns and aspirations into five core values • Identified inclusive design needs in early-stage metaverse education platforms •Informed recommendations for accessibility, user agency, and safety, thereby guiding ethical and empowering development of the metaverse learning for marginalized learners

Table B1 (Continued).

Models and theories used	Frequency and included studies	Application contexts	Relevance
Hierarchical deep reinforcement learning (HRL) with experience sharing	1 (Hare & Tang, 2022)	Applied in an engineering education case study involving university-level computer engineering students using a metaverse game (Gridlock)	• Addressed the technical gap in the metaverse learning by enhancing nonplayer character (NPC) intelligence and personalization •Allowed dynamic adaptation to learners' needs in real-time, improving engagement and content delivery • Demonstrated how AI-driven agents can personalize metaverse education effectively through reinforcement learning
Cognitive load theory	1 (Yang et al., 2024)	Applied in a study in Taiwan involving college students in an art education context	•Explained differences in mental effort between VR-based and screen-based learning environments •Instructional design within the metaverse contexts and guiding the development of cognitively efficient VR learning environments
Sociocultural theory	1 (Chen, 2024)	Involving pre-service EFL teachers in Taiwan using gather metaverse platform for lesson planning and interaction	• Explored how virtual platforms as Gather support collaborative and socially mediated learning • Immersive environments enhanced physical, social, and self-presence • Helped explain how digital social context fosters meaningful interaction, supporting teacher development through shared activities and scaffolded learning within the metaverse
Self-determination theory (SDT)	1 (Pan et al., 2023)	Applied alongside TAM and DOI in a large-scale online survey exploring motivations for adopting the metaverse; targeting participants in China and South Korea	•Interpreted intrinsic motivational factors such as perceived enjoyment and the psychological need for autonomy • Explained user motivation beyond instrumental utility, highlighting how internal psychological needs shape engagement in the metaverse
Construal level theory (CLT)	1 (Kim & Lee, 2023)	Applied in the context of metaverse-based performing arts education in South Korea	• Explained how various dimensions of psychological distance, such as spatial, temporal, social, and artistic, affect users' subjective experience and resistance to engagement with virtual performing arts • Highlighted how users' perception of distance mediates emotional and cognitive responses, identifying artistic distance and subjective experience as key predictors of acceptance or resistance within immersive cultural settings
Innovation resistance theory	1 (Lee & Chaney, 2024)	Applied in investigating psychological and functional barriers to the metaverse adoption among individuals with varying levels of familiarity in France	• Used to understand why users resist adopting the metaverse, framing resistance as a response to perceived risks rather than mere rejection •Identified key barriers such as privacy concerns, loss of social ties, addiction avoidance, and perceived infeasibility • Provided a structured lens to classify resistance motivations and emphasized that resistance can be rational and proactive in the face of disruptive innovations

APPENDIX C

Table C1. Future research topics/themes

Dimensions	Topics/themes	Aspects to be researched
1. Behavior and attitude	(a) Students and teachers' behavioral intentions and attitudes	1. The application of the metaverse technology adoption and acceptance model in education 2. Differences in attitudes between students and teachers or individual differences (such as age, gender, academic background, culture) towards metaverse education 3. Factors influencing the behavioral intention of students and teachers to adopt metaverse educational technology (using models as TAM, UTAUT, UTAUT2, SDT, ECM, TPB, DOI, Flow theory, TTF, PPM)
2. Technology safety and design	(a) Metaverse teaching content, methods design, and development	1. Application of metaverse technology in achieving immersive learning experiences 2. Strategies to enhance learning interactivity and motivation using metaverse technology 3. Designing personalized metaverse learning paths 4. Designing metaverse teaching content and methods that cater to different learning styles 5. Designing metaverse teaching content that meets the needs of different subjects
	(b) Data privacy and security	1. Major risks in data privacy and security in metaverse education 2. How learners and teachers perceive their data privacy in the metaverse 3. Implementing effective data protection and privacy policies on metaverse platforms
3. Teaching and learning	(a) Learner engagement	1. Quantifying learner engagement and differences in engagement among learners with different educational backgrounds in metaverse education 2. Strategies, methods and impact to stimulate learner engagement and interest 3. The effectiveness of gamified learning elements in promoting engagement 4. Changes in motivation and participation before and after the introduction of metaverse education
	(b) Learning experience	1. Students' immersive learning experience in metaverse education 2. Learners' evaluation of user experience on metaverse education platforms 3. Differences in learning experiences across subjects in the metaverse environment 4. Designing metaverse learning activities to enhance learners' emotional experience and satisfaction
	(c) Learning outcome assessment	1. Methods for assessing learning outcomes in the Metaverse education environment 2. Comparison of learning outcomes between metaverse education and traditional education models 3. The effectiveness of peer evaluation and timely feedback in the Metaverse environment 4. The impact of learners' traits (such as self-efficacy, and learning motivation) on learning outcomes in metaverse education
4. Society, culture, and ethics	(a) Ethical and social impact	1. Ethical issues in metaverse education and solutions 2. Challenges and opportunities for achieving educational equity in the metaverse education environment 3. The impact of metaverse technology on learners' identity and self-expression
	(b) Cross-cultural education	1. Cross-cultural communication strategies of learners on metaverse platforms 2. Interaction modes among learners with different cultural backgrounds 3. Whether metaverse education can promote understanding and respect among learners from different cultural backgrounds
5. Teacher development	(a) Teacher training and support	1. Teachers' technology, and knowledge needs in the metaverse teaching environment 2. Innovation and practice in teaching strategies by teachers in the metaverse environment 3. Opportunities and challenges brought to teachers by using metaverse education technology
6. Continuous learning and professional development	(a) Lifelong learning and career development	1. Application and effectiveness assessment of metaverse platforms in vocational skill training 2. The impact of metaverse technology on learners' lifelong learning paths 3. Design and training of career development planning and guidance services in the metaverse environment