Computers in Human Behavior Reports 15 (2024) 100459

Contents lists available at ScienceDirect

Computers in Human Behavior Reports

journal homepage: www.sciencedirect.com/journal/computers-in-human-behavior-reports

Factors impacting users' willingness to adopt and utilize the metaverse in education: A systematic review

Mousa Al-kfairy *, Soha Ahmed, Ashraf Khalil

Zayed University, College of Technological Innovation, Abu Dhabi, United Arab Emirates

A R T I C L E I N F O

Keywords:
Metaverse education
Intention to use
Acceptance
Systematic review
Information systems theories

A B S T R A C T

Purpose: This study explores the factors influencing the adoption and acceptance of Metaverse technologies in educational settings. Despite the growing interest in immersive educational environments provided by the Metaverse, there is a lack of comprehensive understanding regarding the elements that affect user engagement and acceptance. This paper aims to bridge this gap through a systematic review of empirical studies that apply Information Systems theories such as TAM, UTAUT, TPB, and their extensions.
Methods: A total of 35 empirical studies were analyzed using a methodical review approach. The research methodologies employed in these studies include surveys, structural equation modeling, and interviews, providing a broad spectrum of data on how different factors influence educational outcomes in the Metaverse.
Results: The findings reveal that user adoption of the Metaverse in educational contexts is influenced by multiple factors at individual, technological, and environmental levels. Key factors identified include effort expectancy, behavioral intention, self-efficacy, enjoyment, and immersion. These factors are subject to moderating effects, suggesting that the dynamics of Metaverse adoption are highly context-dependent.
Conclusion: The insights gained from this review provide valuable guidelines for educators, policymakers, and technology developers aiming to effectively integrate Metaverse technologies into educational frameworks. The study also outlines limitations and suggests directions for future research, highlighting the need for further investigations into the longitudinal impacts and cultural adaptability of Metaverse applications in education.

1. Introduction

The digital transformation of education has been a topic of intense exploration and development over recent decades, reflecting broader changes in how technology influences human activities. This introduction examines the evolution of educational technology from traditional classrooms to the Metaverse. We begin by discussing the integration of early digital technologies in education and the transition towards more immersive learning environments facilitated by virtual reality (VR) and augmented reality (AR). Our focus is on exploring the historical context, technological advancements, and the recent pandemic-driven adoption of these technologies.

1.1. Historical context

The evolution of e-learning systems from traditional classrooms to sophisticated digital platforms has culminated in exploring immersive learning environments facilitated by technological advancements. Initially, traditional learning, characterized by face-to-face instruction within physical classrooms, transitioned to e-learning with the advent of the internet and digital technologies. These early e-learning systems, which aimed to replicate traditional teaching methods digitally, provided online access to documents, videos, and assessments. This allowed for flexible learning schedules and distance education, significantly broadening the scope of educational opportunities. Rosenberg's seminal work on the early integration of digital technologies in education provides a detailed examination of this phase (P & Rosenberg, 2001, pp. 169–174).

As technology evolved, e-learning systems incorporated more interactive elements like forums, real-time discussions, and collaborative projects. Anderson's research details this shift towards interactive, learner-centered platforms that engage students in active learning processes (Anderson, 2008). Concurrently, the introduction of mobile technology further enhanced e-learning through mobile learning (m-learning), utilizing the ubiquity and portability of mobile devices to facilitate access to educational content anytime, anywhere. Sharples

* Corresponding author.
E-mail addresses: Mousa.al-kfairy@zu.ac.ae (M. Al-kfairy), suha.glal@gmail.com (S. Ahmed), Ashraf.Khalil@zu.ac.ae (A. Khalil).

https://doi.org/10.1016/j.chbr.2024.100459
Received 18 May 2024; Received in revised form 7 July 2024; Accepted 9 July 2024
Available online 14 July 2024

et al. emphasize how m-learning supports a more situated, collaborative, and personalized learning experience, highlighting its importance for lifelong and informal education (Sharples et al., 2007).

1.2. Technological advancements

The latest advancement in e-learning—immersive learning environments—is driven by virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies. These technologies provide experiential learning through simulations of real-world scenarios, effectively used in medicine, engineering, and science. Dede discusses how these immersive technologies combine the engagement of real-world environments with the flexibility of digital adjustments to tailor educational experiences (Dede, 2009).

1.3. Current trends and pandemic-driven adoption

The COVID-19 pandemic highlighted the critical role of digital technologies in maintaining educational continuity. The widespread adoption of video conferencing tools during the pandemic was instrumental in ensuring that educational activities could continue, even when traditional in-person instruction was not feasible. This experience has demonstrated the potential of digital platforms to support education during crises and beyond.

Emerging technologies like the Metaverse, a virtual reality space where users interact within a computer-generated environment, offer further opportunities to transform educational methods. The concept of the Metaverse traces its origins to the realm of science fiction. The term "Metaverse" itself was introduced by Neal Stephenson in his 1992 novel "Snow Crash," where he envisioned a virtual reality space where users, represented by avatars, could interact with each other and computer-generated environments. This idea captured the imaginations of technologists and creators, influencing the development of early virtual worlds and online games. Over the decades, technological advancements, particularly in virtual reality (VR), augmented reality (AR), and blockchain, have transformed the concept from fiction to a potential future framework for digital interaction. Today, "Metaverse" refers to a collective virtual shared space created by the convergence of virtually enhanced physical and digital reality, where people can meet, work, and play across different platforms (Mystakidis, 2022).

However, despite its promising capabilities, the Metaverse has not yet achieved widespread acceptance in educational settings, indicating a need to further explore its potential and limitations. Researchers like Kraus et al. underscore the need for rigorous investigation into understudied yet practically significant trends such as generative artificial intelligence and Metaverse technologies (Kraus et al., 2023).

1.4. Scope and objectives

The primary aim of this systematic review is to identify and synthesize the factors that influence users' willingness to adopt and utilize the Metaverse within educational settings. The review systematically examines empirical studies that have applied Information Systems theories such as the Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), Theory of Planned Behavior (TPB), and their extensions to explore these factors. By evaluating 35 empirical studies, we aim to provide a comprehensive understanding of the determinants affecting the adoption of the Metaverse in education.

1.4.1. Research questions

To achieve this aim, our review is guided by the following specific research questions.

1. What individual-level factors influence users' willingness to adopt the Metaverse in educational settings?
2. What technological-level factors impact the acceptance and use of the Metaverse for learning purposes?
3. How do environmental-level factors affect users' intention to employ the Metaverse in educational contexts?
4. What research methods have been employed in the existing literature to investigate these factors?
5. Are there any moderating effects that indicate the context-dependent and dynamic nature of users' intentions to use the Metaverse in education?

These research questions aim to summarize the current state of knowledge by identifying prevalent themes, patterns, and emerging trends within existing literature. By studying the key findings, this systematic review will enhance the understanding of the factors that significantly influence users' intention to use and adopt the Metaverse in educational contexts. This knowledge will foster evidence-based decision-making for educators, policymakers, and researchers endeavoring to implement and harness the Metaverse effectively within educational environments.

1.4.2. Specific contributions

This review makes several key contributions to the field.

1. **Comprehensive Synthesis:** By consolidating findings from various empirical studies, this review provides a holistic view of the factors influencing the adoption and utilization of the Metaverse in education.
2. **Methodological Insights:** The paper examines the research methods used in the studies, providing insights into how different methodological approaches contribute to understanding the adoption of the Metaverse.
3. **Contextual Understanding:** The review highlights the context-dependent and dynamic nature of users' intentions, offering valuable insights for educators and policymakers to tailor Metaverse implementations effectively.
4. **Future Research Directions:** By identifying limitations in the current studies and suggesting future research directions, this review paves the way for more focused and impactful research in the domain of educational technology and Metaverse applications.

1.4.3. Out of scope considerations

While this review aims to provide a comprehensive understanding of the factors influencing the adoption of the Metaverse in education, certain aspects are beyond the scope of this study. These include.

- **Impact on Learning Outcomes:** Exploring the direct impact of Metaverse technologies on learning outcomes, including any evidence or studies demonstrating how these technologies enhance or hinder educational performance and engagement.
- **Policy and Regulation:** Addressing the role of policy and regulation in shaping the development and use of the Metaverse in education. This includes discussing existing policies, potential regulatory challenges, and the need for new frameworks to support innovation while ensuring safety and equity.
- **Technical Challenges and Solutions:** Providing an in-depth analysis of the technical challenges associated with implementing Metaverse technologies in educational contexts, along with potential solutions and innovations that could overcome these challenges.
- **Interdisciplinary Approaches:** Highlighting the importance of interdisciplinary approaches in the development and application of Metaverse technologies, and how collaboration between fields such as computer science, education, psychology, and design can lead to more effective and innovative solutions.

These areas, while significant, are not covered in this study and warrant further research to fully understand their implications within the educational domain.

This review is organized into several key sections to systematically address the factors influencing the adoption of the Metaverse in educational settings: Section 2, Literature Review, explores the evolution and conceptual development of virtual worlds. Section 3, Methodology, outlines our research strategies and assessment methods. Section 4, Results, presents the findings on influential factors. Section 5, Discussion, discusses the implications and future research directions. Finally, Section 6, Conclusion, summarizes our findings and their implications for stakeholders in education.

2. Literature Review

This section delves into the historical and technological evolution of virtual environments, from early virtual worlds to the sophisticated realms of augmented reality (AR) and virtual reality (VR), culminating in the development of the Metaverse. This exploration not only highlights the technological progression but also sets the context for understanding the current and potential applications of the Metaverse in educational settings.

2.1. Overview of early virtual worlds

Virtual worlds like Second Life and Active Worlds have been significant in the evolution of online interactions. These platforms, emerging in the late 1990s and early 2000s, provided users with immersive digital environments for interaction, creation, and engagement(Schroeder et al., 2001).

Second Life, launched by Linden Lab in 2003, became the largest social virtual world with over fifteen million registered users. It allowed users to create avatars, build virtual properties, and participate in a virtual economy, fostering creativity and a sense of ownership among participants (Johnson, 2006, pp. 1–15).

Active Worlds, developed earlier and officially launched on June 28, 1995, provided a 3D virtual environment where users could create and explore digital spaces. It pioneered features such as customizable avatars and user-built environments, which later became standard in virtual worlds (Bartle, 2004; Schroeder et al., 2001).

Early virtual worlds evolved from text-based games, starting with Multi-User Dungeons (MUDs) in 1979. These text-based environments allowed players to navigate and interact using text commands. The development of TinyMUDs in 1989 introduced social and creative elements, allowing users to build and modify objects within the virtual world (Taylor, 2009). The evolution continued with MOOs (Multi-User Object Oriented), enabling users to create and interact with content. This development paved the way for MMORPGs (Massively Multiplayer Online Role-Playing Games), such as Ultima Online and EverQuest, which introduced graphical interfaces and required collaborative play (Castronova, 2005).

The lessons learned from these early virtual worlds emphasize the importance of community engagement, user-generated content, and robust technological infrastructure. These elements are crucial for successfully implementing and adopting the Metaverse in educational settings.

2.2. Evolution of AR and VR technologies

Over the past two decades, augmented reality (AR) and virtual reality (VR) technologies have undergone significant advancements, evolving from rudimentary prototypes to sophisticated devices that offer immersive experiences across various domains, including education, entertainment, and healthcare.

The concept of virtual reality dates back to the 1960s and 1970s, with several key milestones marking its early development. One of the pioneering figures in VR technology was Ivan Sutherland, who, along with his student Bob Sproull, developed the first VR headset known as the “Sword of Damocles” in 1968 (Sutherland, 1968). This headset was a head-mounted display system that provided a rudimentary form of VR, offering users a 3D experience by tracking their head movements.

In the 1970s, Myron Krueger’s development of “Videoplace” further advanced VR technology. Videoplace was an artificial reality system that allowed users to interact with digital environments using their body movements, laying the groundwork for future interactive VR systems (Krueger et al., 1985). Another significant milestone in the early development of VR was the creation of the Aspen Movie Map in 1978 by MIT, which allowed users to take a virtual tour of Aspen, Colorado, demonstrating the potential of VR for creating immersive, navigable environments (Lippman, 1980).

Fast forward to the 21st century, one of the key milestones in modern VR technology was the development of the Oculus Rift, introduced by Palmer Luckey in 2012. This device revitalized interest in VR by offering a high-quality, immersive experience at a relatively affordable price point (Harley, 2020). Following the success of the Oculus Rift, other major companies entered the VR market, leading to rapid advancements in the technology.

Microsoft’s HoloLens, introduced in 2015, marked a significant milestone in AR technology. The HoloLens is a mixed reality headset that overlays digital information onto the physical world, enabling users to interact with holograms within their environment (Noor, 2016). This device has found applications in fields such as medical training, architecture, and manufacturing.

Other notable AR and VR devices include the HTC Vive, released in 2016, which provided room-scale VR experiences with precise motion tracking (Egger et al., 2017), and the Magic Leap One, introduced in 2018, which combined AR and VR elements to create a unique mixed reality experience (Serrano et al., 2022).

These technological advancements have expanded the possibilities for immersive learning and interactive experiences, making AR and VR integral components of the Metaverse. The lessons learned from these developments emphasize the importance of community engagement, user-generated content, and robust technological infrastructure, which are crucial for the successful implementation and adoption of the Metaverse in educational settings.

2.3. Development of the metaverse concept

The emergence of the Metaverse is expected to transform several industries, including technology and engineering management. The potential and difficulties presented by this fresh realm call for scholarly investigation. The Metaverse catalyzes the development of unheard-of collaborative learning environments where augmented (AR) and virtual reality (VR) have completely changed our lives. According to academic predictions, these technologies will enable students and teachers from all backgrounds to collaborate and communicate seamlessly, enhancing global learning experiences (Bower, 2019). The Metaverse is also anticipated to serve as a hub for virtual labs and simulations, democratizing access to practical learning and opening the door for experiential learning that replicates real-world scenarios, redefining conventional pedagogical strategies in the technology and engineering sectors (See Fig. 1 for the development history of AR/VR).

However, shifting to a Metaverse-centric educational paradigm raises some difficult issues, particularly intellectual property management. This new digital frontier calls for a balanced strategy that fosters innovation while defending the rights of creators and stakeholders (De Filippi et al., 2018). Additionally, the formation of ethical frameworks and practices to responsibly govern technology management within the Metaverse is urged due to the scholarly community’s need to address impending ethical and privacy concerns, which are characterized by potential data misuse, increased surveillance, and growing digital inequality (Dignum, 2019).In addition, for the Metaverse to completely realize its educational potential, stable, secure, and fast internet connections are essential (Al-Fuqaha et al., 2015). These developments in infrastructure and connectivity are crucial to the Metaverse’s effective

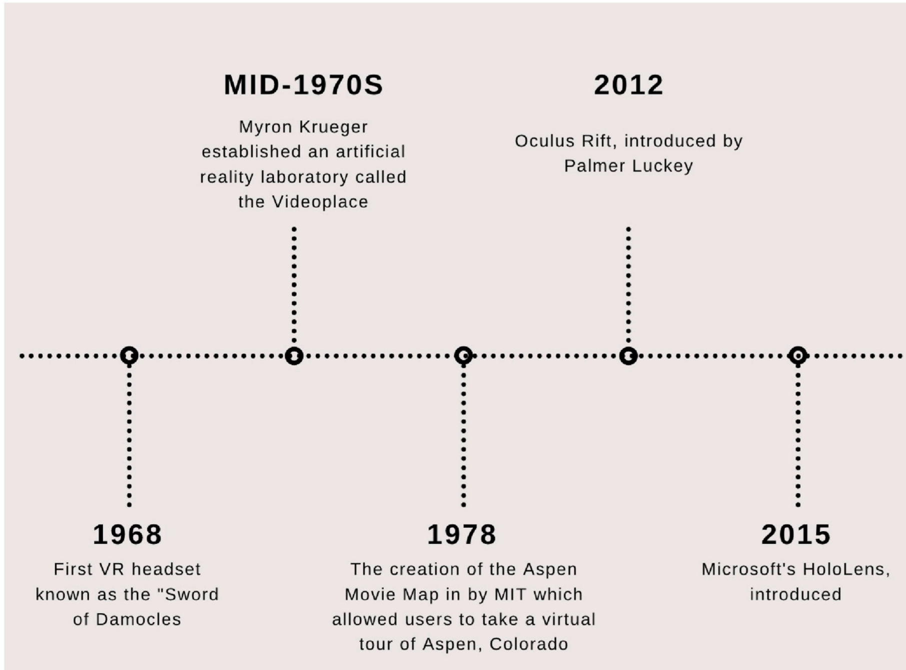

Fig. 1. Evolution of augmented reality (AR) and virtual reality (VR).

integration. To navigate the developing discourse and real-world applications that the Metaverse unfolds, the academic community should actively engage in ongoing research and strategic implementation as the educational sector stands on the edge of this revolution.

2.4. Technology adoption models and theories

Understanding how individuals and organizations adopt new technologies is crucial for successful innovation management, marketing strategies, and policy-making. To this end, several models have been developed to analyze and predict the factors influencing technology acceptance and diffusion. These models offer frameworks delineating the psychological and social drivers that prompt users to adopt new technologies. Among the most influential of these frameworks are the Technology Acceptance Model (TAM), the Unified Theory of Acceptance and Use of Technology (UTAUT), the Diffusion of Innovations (DOI), the Consumer Adoption Process (CAP), and the Theory of Planned Behavior (TPB). Each model provides a unique perspective on the adoption process, utilizing various constructs and theories to explain different aspects of user behavior and technology acceptance. This subsection explores the different developed models over time.

2.4.1. Diffusion of innovations (DOI)

Everett Rogers' Diffusion of Innovations (DOI), first published in 1962, is a seminal framework in studying how new ideas and technologies are taken up and spread across social systems. This model is fundamental in understanding the adoption lifecycle of innovations and is extensively applied in fields such as marketing, sociology, information technology, and public health. The model breaks down the adoption process into several key elements that influence how quickly and widely an innovation is adopted. These elements are Innovativeness, Compatibility, Complexity, Trialability, and Observability. Each construct plays a critical role in determining the success and rate of adoption of new ideas. Below is a detailed look at each of these constructs (Dearing & Cox, 2018).

Innovativeness refers to the degree to which an innovation is perceived as being new or different compared to the existing norms. It's not just about the objective novelty of the idea or technology; it's about how potential adopters perceive it as new or revolutionary. Innovations that are seen as highly innovative can sometimes face more resistance due to the uncertainty and changes they bring. However, if perceived positively, high innovativeness can accelerate adoption among those who are more adventurous and open to change (Dearing & Cox, 2018).

Compatibility measures how well the innovation fits with the intended users' existing values, past experiences, needs, and existing systems. A high degree of compatibility helps in smoother integration of the innovation, as it aligns with the adopters' lifestyles, values, or work practices. When users perceive innovation as compatible, they are more likely to adopt it since it does not require radical changes to their current habits or environments (Dearing & Cox, 2018).

Complexity denotes the perceived difficulty of understanding and using the innovation. The more complex an innovation is perceived to be, the slower its adoption rate. Simplicity, on the other hand, facilitates quicker adoption as potential users are less intimidated by the learning curve. Reducing complexity through design improvements or effective user training and support can enhance the adoption rates (Dearing & Cox, 2018).

Trialability is the extent to which an innovation can be experimented with on a limited basis before making a full-scale commitment. This construct is crucial because it allows potential adopters to explore the innovation and see firsthand its benefits without a significant initial investment or risk. Innovations that are easily trialable typically spread faster as they reduce potential users' uncertainty about the innovation's effectiveness and utility (Dearing & Cox, 2018).

Observability involves the visibility of the results or benefits of the innovation to others. When the benefits of an innovation are easily observed and understood by potential adopters, they are more likely to adopt the innovation themselves. Observability can be a powerful motivator for adoption, providing tangible evidence of the innovation's value and effectiveness and encouraging others in the social system to adopt (Dearing & Cox, 2018).

Together, these constructs offer a comprehensive view of the various factors that can affect the diffusion of innovations within a society. Rogers' model helps innovators and marketers design better adoption strategies by addressing these key factors, ultimately enhancing the uptake of new technologies or ideas.

2.4.2. Theory of Planned Behavior (TPB)

The Theory of Planned Behavior (TPB) is an insightful psychological model developed by Icek Ajzen to enhance the predictive power of the Theory of Reasoned Action by including behavioral intentions as a key mediator in situations where individuals do not have complete control over their actions. It's particularly effective in understanding behaviors influenced by both internal attitudes and external social pressures and has been applied in diverse fields such as health, environmental behavior, and consumer behavior. The following defines each construct (Ajzen, 1991).

Attitude toward the behavior is the personal appraisal of performing the behavior, encompassing both positive and negative evaluations. This construct is formed from an individual's beliefs about the outcomes of the behavior, each assessed in terms of its significance. For instance, if an individual believes quitting smoking will significantly benefit their health and highly values health improvement, this positive evaluation contributes to a favorable attitude toward quitting smoking. Attitudes are key drivers in shaping the intention to engage in a behavior, as they reflect the individual's overall feeling about the action's merits (Ajzen, 1991).

Subjective norms refer to the perceived social pressures to perform or avoid certain behaviors. This construct reflects the perceived expectations of important others, such as family, friends, or peers, and the individual's motivation to comply. For example, if a person perceives that most of their close peers and family members are opposed to gambling, this social pressure can significantly influence their decision-making regarding gambling activities. Subjective norms highlight the social context of decision-making, indicating how perceived social approval or disapproval affects behavioral intentions (Ajzen, 1991).

Perceived behavioral control involves the individual's perceptions of the ease or difficulty of performing the behavior, influenced by personal experience and anticipated obstacles. This construct is akin to self-efficacy and addresses situations where control over behavior is incomplete. For example, a person may intend to diet and believe it is a good decision but might perceive great difficulty due to a lack of knowledge about nutrition or a busy work schedule that limits time for meal planning. This perception can deter the actual implementation of the dieting behavior, as perceived behavioral control directly impacts both the strength of the behavioral intention and the behavior itself (Ajzen, 1991).

Each of these constructs—attitude, subjective norms, and perceived behavioral control—work together to shape an individual's behavioral intentions, which, in turn, predict actual behavior. TPB helps elucidate how these dimensions influence decisions in real-world scenarios, offering a valuable framework for designing interventions that can effectively alter behaviors.

2.4.3. Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) was introduced by Fred Davis in 1986. Designed to predict and explain user acceptance of information technology, TAM is rooted in the Theory of Reasoned Action (TRA). This well-established psychological theory explains human behavior through specific beliefs. TAM simplifies the broad concepts of TRA to specifically address computer usage behavior, making it a pivotal tool in information systems research (Maranguni et al., 2015). TAM consists of the following constructs:

Perceived Usefulness is one of the core constructs of TAM and is defined as the degree to which a person believes that using a particular technology will enhance their job performance. This belief is based on the assumption that implementing the technology will bring clear benefits to the user, such as increased efficiency, productivity, or effectiveness in their job roles. For instance, a user might perceive a new data analysis software as useful if it is believed to dramatically reduce the time needed to process information and generate reports. This perceived benefit significantly influences the motivation to adopt and use the technology (Maranguni et al., 2015).

The second core construct of TAM, Perceived Ease of Use, refers to the degree to which a person believes that using a particular technology will be free of physical and mental effort. This construct focuses on the user's subjective assessment of the ease with which the technology can be learned and operated. Technologies perceived as easy to use are more likely to be embraced because they are seen as accessible and straightforward. For example, software with an intuitive user interface that minimizes learning time is considered easier to use, increasing its chances of acceptance and adoption (Maranguni et al., 2015).

2.4.4. Unified Theory of Acceptance and Use of Technology (UTAUT)

The Unified Theory of Acceptance and Use of Technology (UTAUT), developed by Venkatesh et al., in 2003, integrates elements from eight existing technology adoption models, including the Technology Acceptance Model (TAM) and the Theory of Planned Behavior (TPB). This synthesis aimed to create a comprehensive framework to better understand technology adoption, particularly in organizational settings. UTAUT has been instrumental in examining the broader array of factors that influence the acceptance and use of technology (Venkatesh et al., 2003). The theory includes the following set of constructs.

Performance Expectancy, which originates from "perceived usefulness" in TAM and "extrinsic motivation" from the Motivational Model, is the belief that technology will improve performance. This construct emphasizes the expected benefits, such as increased efficiency, effectiveness, and productivity, that users anticipate from the technology. It is considered one of the strongest predictors of technology acceptance (Venkatesh et al., 2003).

Effort Expectancy evolved from "perceived ease of use" in TAM and "complexity" from the Model of PC Utilization. It refers to the ease associated with the use of the technology. This construct assesses how user-friendly and accessible the technology is perceived, which significantly impacts its adoption. The easier the technology is to use, the more likely individuals will adopt it (Venkatesh et al., 2003).

The construct of Social Influence is related to the "subjective norm" in TPB and TAM2 and "social factors" in the Motivational Model. It deals with the extent to which an individual perceives that important others, such as peers and supervisors, believe they should use the technology. This reflects the social pressures and influences that can significantly sway an individual's decision to adopt new technology (Venkatesh et al., 2003).

Originating from "perceived behavioral control" in TPB and the concept of "facilitating conditions" in the Model of PC Utilization, Facilitating Conditions involve the degree to which an individual believes that organizational and technical support is available to assist in using the technology. This includes the presence of resources, IT support, and the overall infrastructure that can ease the technology's integration into daily usage (Venkatesh et al., 2003).

However, recognizing the changing dynamics of technology use, Venkatesh et al. introduced an extension to the original model named UTAUT2 in 2012. This update adds three new constructs: Hedonic Motivation, which reflects the pleasure derived from using the technology; Price Value, which considers the technology's cost relative to its perceived benefits; and Habit, which assesses the degree to which the use of the technology becomes automatic through repeated use. These additions enhance the model's applicability to consumer technology adoption, acknowledging factors like enjoyment, cost, and habitual usage that significantly influence consumer decisions (Tamilmani et al., 2021).

UTAUT2 thus broadens the scope of the original UTAUT model, providing a deeper understanding of how various factors, including enjoyment and cost considerations, affect technology adoption in personal and non-organizational contexts.

2.5. Gaps in existing literature

While significant advancements have been made in understanding the technological evolution and adoption of virtual environments, there remain substantial gaps in the literature, particularly concerning the educational application of the Metaverse. Current research often overlooks the nuanced factors that affect the integration and acceptance of such technologies within educational frameworks. There is a need for a more detailed exploration of the specific adoption barriers, the pedagogical implications of immersive learning environments, and the infrastructural requirements to support such technologies. Additionally, the potential long-term impacts on educational outcomes and equity in access to these technologies are not adequately addressed. Addressing these gaps will provide clearer guidance for educators, policymakers, and technologists in effectively implementing and leveraging the Metaverse in educational contexts.

3. Methodology

This systematic review adheres to the updated guidelines provided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Page et al., 2021).

3.1. Search strategies

A systematic search approach was utilized to identify pertinent studies on the employment of the Metaverse in education. The search was carried out in multiple electronic databases, comprising Scopus, Google Scholar, DBLP: Computer Science Bibliography, The International Prospective Register of Systematic Reviews (PROSPERO), Cochrane Database of Systematic Reviews (CDSR), and Scientific Electronic Library Online (Scielo). These databases were chosen for their comprehensive coverage, relevance to the field, and accessibility. Scopus and Google Scholar provide extensive multidisciplinary coverage and include peer-reviewed journal articles, conference papers, and other scholarly literature. DBLP specializes in computer science, ensuring the inclusion of technical and research-focused studies. PROSPERO, CDSR, and Scielo are recognized for their contributions to systematic reviews and health-related research, offering high-quality, peer-reviewed articles that support the rigorous analysis required for a systematic review. Search terms were formulated using controlled vocabularies and keywords. The search strategy consisted of two groups of words: (1) the method and the body area of interest (Metaverse); and (2) the factor of interest (education, learning, teaching). This resulted in the following search strings: "Metaverse and education" (Topic) OR "Metaverse and learning" (Topic) OR "Metaverse and teaching" (Topic). The search strings were tailored to each database's specific syntax and capabilities. The exact search terms and keywords used (including any Boolean operators) and the number of documents retrieved from each database are presented in Table 1. It should be noted that no filters were applied. The data collection process involved utilizing various Python code snippets to enhance efficiency and streamline the acquisition of paper titles and abstracts. Python code was employed to download search results from Google Scholar and format the obtained results from DBLP using Google Colab. Python code was also utilized to identify and eliminate duplicate papers. The code development involved leveraging ChatGPT to assist in automating tasks such as acquiring titles and abstracts, removing duplicates, and formatting data.

Data from Scopus and Web of Science did not require additional formatting or processing and were directly downloaded as Excel spreadsheets using the available options. However, the results were manually inputted into a Google Sheet due to the limited availability of data from sources such as Scielo, CDSR, and PROSPERO.

The adoption of Python code snippets facilitated the efficient collection and processing of paper titles and abstracts. While some databases provided readily useable data, others necessitated the implementation of customized code for data manipulation and extraction. Combining automated procedures and manual input ensured comprehensive coverage of the literature for the systematic review.

Table 1
Electronic databases searched and search strings and number of documents retrieved from each database.

Database	Search String	Doc.	Start Date	End Date
Scopus	TITLE-ABS-KEY (Metaverse AND (educa* OR learn* OR teach*))	511	3/30/2023	May 4, 2023
Web of Science	(Metaverse AND (educat* OR learn* OR teachI *))	415	3/30/2023	May 4, 2023
Google Scholar	allintitle: Metaverse teaching OR learning OR education	404	3/30/2023	4/25/2023
DBLP: computer science bibliography	Metaverse$ educat| learn| teach	84	3/30/2023	4/26/2023
The International Prospective Register of Systematic Reviews (PROSPERO)	Metaverse AND (education OR learning OR teaching)	8	3/30/2023	April 4, 2023
Cochrane Database of Systematic Reviews (CDSR)	Title Abstract Keywords (Metaverse AND educat OR Metaverse AND learn OR Metaverse AND teach)	1	3/30/2023	April 4, 2023
Scientific Electronic Library Online (Scielo).	Metaverse AND education OR learning OR teaching	0	3/30/2023	April 4, 2023

3.2. Inclusion criteria

In our systematic review, studies were selected based on stringent eligibility criteria adhering to the PICO framework. Table 2 outlines our eligibility criteria in a structured format, aligned with the well-recognized PICO model, which includes Population, Intervention, Comparator, Outcome, and an additional component for Study Characteristics.

3.2.1. Study selection and screening process

An extensive search across seven databases resulted in the identification of 1423 articles. The dates corresponding to the last search of each database are detailed in the provided table (Table 1). Following this, duplicate entries amounting to 439 were removed. In addition, a Python script was employed to identify and remove articles ($n = 28$) whose titles corresponded to conference names. Consequently, 956 articles were left for title and abstract review. Two authors (MAK and SGA) reviewed all 956 article titles, and any discrepancies were addressed by a third author (AFK). This step resulted in the exclusion of 549 articles.

Then, the retrieval of full-text potentially eligible studies ($n = 411$) was automated by developing a Python code, which proved instrumental in expediting the process. Leveraging the Elsiver, Springer, and Unpaywall APIs, 241 papers were successfully obtained automatically. To ensure accuracy, these records underwent manual verification by the reviewer (SGA) to confirm they match the title of the potentially eligible studies. 37 incorrectly downloaded papers were identified during the verification process, while the remaining 204 were accurately retrieved.

For the remaining papers, a combination of methods was employed. The manual acquisition was utilized to retrieve 117 papers. Some papers were acquired manually by utilizing existing university subscriptions, while others were accessed through the interlibrary loan service. Unfortunately, 94 papers could not be obtained due to either requiring a paid subscription or their full text not being available.

Integrating automation tools and Python code significantly expedited the data collection, ensuring efficiency and accuracy. The combination of automated retrieval and manual acquisition enabled comprehensive coverage of the literature relevant to the systematic review.

Upon completion of this stage, the full texts of the 317 eligible articles were independently skimmed by two authors (MAK and SGA). This process led to the further exclusion of 249 articles. Subsequently, a

Table 2
Eligibility criteria for the selection of studies in the systematic review following PICO framework.

Criteria	Inclusion	Exclusion
Population	Studies concerning users or potential users of the Metaverse in an educational scenario, such as students, teachers, instructors, or any individuals engaged in educational activities.	Studies not focusing on users or potential users of the Metaverse in educational scenarios.
Intervention	Studies exploring the deployment of the Metaverse in education, including the integration and use of Metaverse technologies, platforms, or applications for instructional purposes.	Studies not concerning the deployment or use of the Metaverse in educational contexts.
Comparator	Studies comparing different factors impacting users' propensity to use and acceptance of the Metaverse in the educational sector.	Studies lacking a clear comparison for factors impacting Metaverse use and acceptance in education.
Outcome	Studies gauging users' intention to use and accept the Metaverse in the educational sector, including attitudes, perceptions, beliefs, or behaviors towards the Metaverse as an educational instrument or platform.	Studies not measuring users' intention to use and accept the Metaverse in the educational sector.
Study Characteristics	Empirical studies such as quasi-experimental, observational, and randomized controlled trials conducted in any educational environment, published within the past 10 years, in English, and peer-reviewed articles published in journals, book chapters, or conference proceedings.	Studies outside the specified date range, not published in English, or not peer-reviewed. Unpublished reports and grey literature.

single reviewer (SGA) performed a full-text review of 68 studies. Two additional studies were excluded following consultations with the reviewer (MAK). The excluded 251 articles did not meet the criteria for inclusion due to reasons such as lack of data on the specified outcomes (n = 221), articles not in English (n = 25), articles not being peer-reviewed publications such as a book chapter, journal, or conference proceeding (n = 5), and not being empirical research studies (n = 31). The selection process, conforming to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology, is graphically represented in Fig. 2.

Out of the final 66 studies included in this systematic review, a substantial fraction (n = 39) were published in 2022, as depicted in Fig. 3. Fig. 4 illustrates the distribution of the final 66 studies based on their type. Similarly, Fig. 5 portrays the distribution of these studies according to their publication type (in a book, journal, or conference).

The 66 studies assessed for eligibility include the following: one was identified as an opinion paper ((GÜ et al., 2022)), while two were classified as bibliometric analyses ((Battal et al., 2022; BICEN & ADEDOYIN, 2022)) and two concept papers ((Bakhri & Sofyan, 2022; Ruwodo et al., 2022)), these studies were excluded from this systematic review since they are not empirical research studies. Table 3 presents the distribution of the reviews and systematic reviews identified, with 11 categorized as review papers and 15 categorized as systematic reviews. These studies were also excluded from this systematic review, and they were not quasi-experimental studies, observational studies, or randomized controlled trials.Table. 4

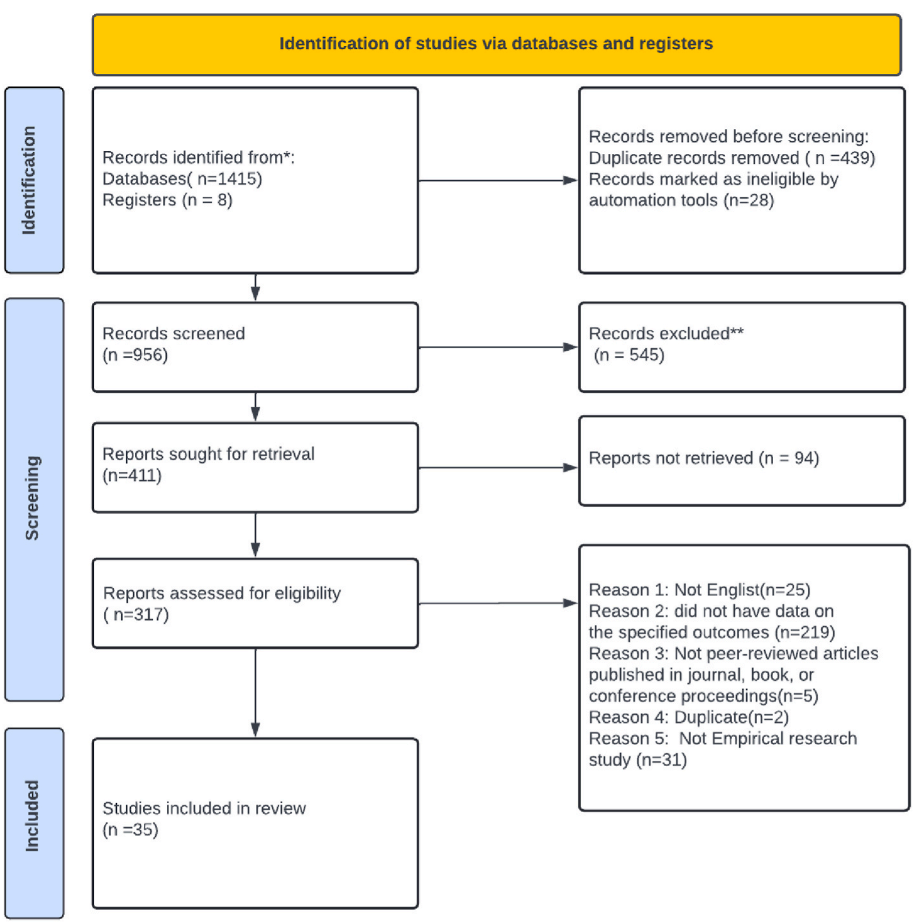

Fig. 2. PRISMA 2020 flow diagram for this review (new, searches of databases and registers).

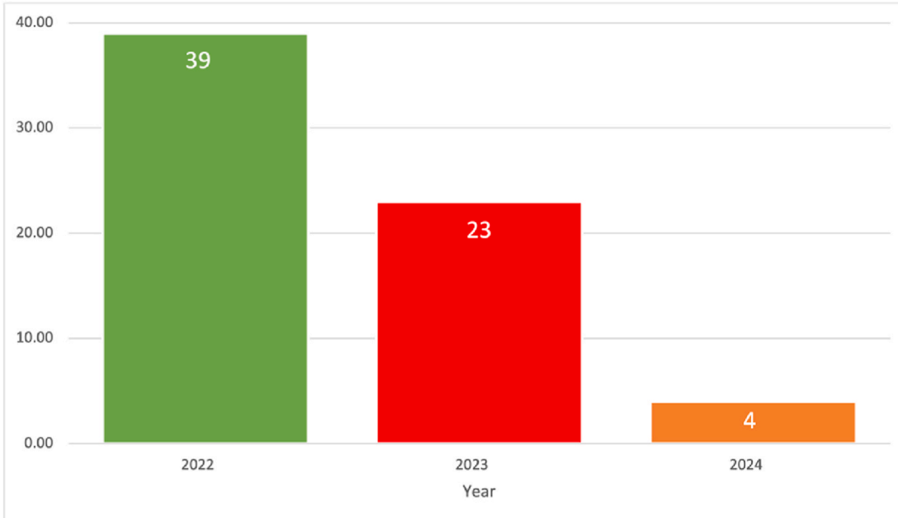

Fig. 3. Distribution of the final 66 studies assessed for inclusion based on publication year.

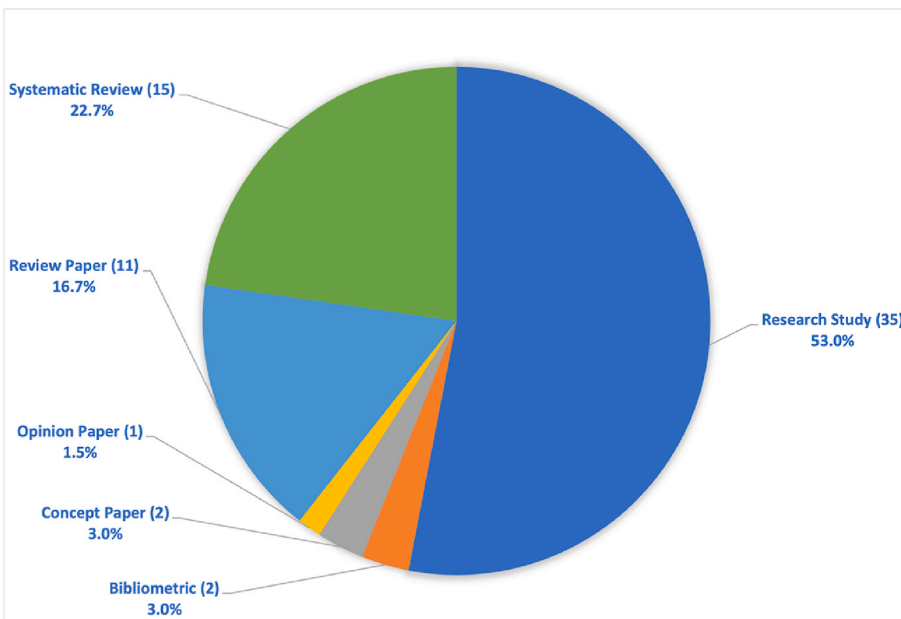

Fig. 4. Distribution of the final 66 studies assessed for inclusion based on their type.

3.3. Data extraction process

This subsection outlines the systematic procedures used for data collection, extraction, and summarization, adhering to rigorous methodological standards to ensure the reliability and comprehensiveness of our systematic review. We detail the development and implementation of specialized data extraction sheets and describe the steps taken to gather and refine data from selected studies.

3.3.1. Data collection

The following steps were performed for data collection.

(1) Development of Data Extraction Sheets: Two data extraction sheets were developed for the systematic review. The first sheet was designed to classify the included studies. It contained the following fields: title, publication (e.g., Computers and Education, Heliyon, International Conference on Virtual Learning), year, publisher (e.g., Elsevier, IEEE), scientific paper type (e.g., research study, bibliometric analysis, concept paper, opinion paper, review paper, systematic review), and publisher type (e.g., conference, book chapter, journal). Scientific papers can be classified into various types based on their content, purpose, and structure. Below are the four types that were identified:
   (a) Empirical Research Studies: These papers present original research findings, methodologies, and data. They typically follow a standard structure, including an abstract, introduction, methodology, results, discussion, and conclusion.
   (b) Review Papers: Review papers provide a comprehensive overview and analysis of existing research on a specific topic. They summarize and critically evaluate the findings of multiple studies, identify trends, and offer new perspectives or recommendations.
   (c) Opinion Papers: Opinion or commentary papers express the author's viewpoint or perspective on a specific scientific

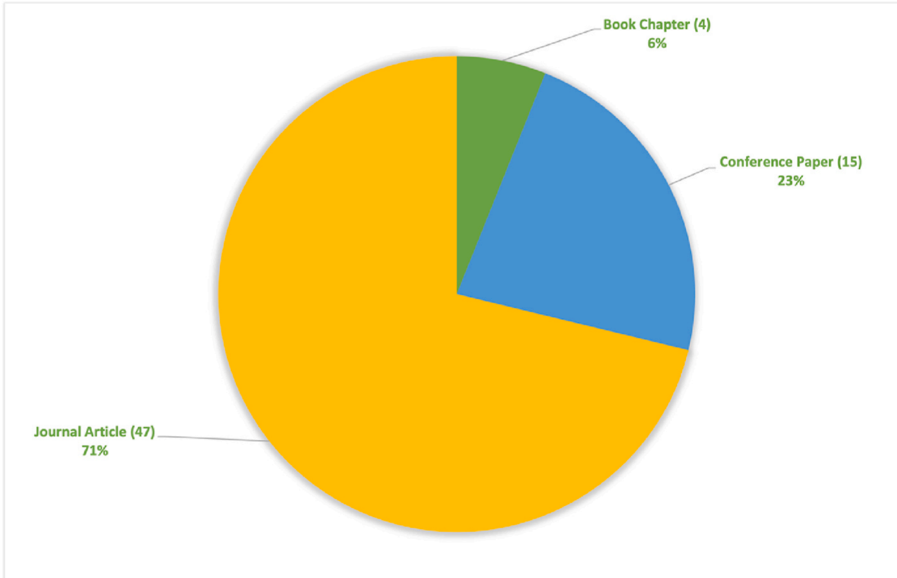

Fig. 5. Distribution of the final 66 studies assessed for inclusion based on their publication type.

topic. They may critique existing research, propose new ideas, or discuss a field's implications and future directions.
   (d) Conceptual Papers: Conceptual papers present new conceptual frameworks, theories, or models. They aim to introduce novel ideas, propose theoretical frameworks, or explore new perspectives on existing theories or phenomena.
   (e) Meta-analyses or Systematic Reviews: These papers synthesize and analyze data from multiple studies to draw overarching conclusions or identify patterns across a body of research. They often involve statistical analysis to combine and compare findings.
2. Second Data Extraction Sheet: A second data extraction sheet was used to extract data from papers identified as empirical research studies in the first data extraction sheet. This second sheet included the following fields:
   (a) Study Title
   (b) Characteristics of Participants: Total count of participants, distribution of gender, age range, and educational background.
   (c) Objective of the Study: Investigating users' readiness to adopt and embrace the Metaverse within educational environments.
   (d) Methodological Approach: Utilization of methodologies such as Structural Equation Modeling (SEM), exploratory factor analysis, confirmatory factor analysis, common method bias model analysis, first-order confirmatory factor analysis, and one-way ANOVA, among others.
   (e) Computational Tools: Employment of software tools like SmartPLS, IBM SPSS, Weka, etc.
   (f) Data Collection Instruments: Usage of surveys, online questionnaires, interviews, and others.
   (g) Validation of Internal Consistency: Examination of construct reliability through the assessment of Cronbach's alpha (CA), composite reliability (CR) or Dijkstra-Henseler's alpha (PA). The construct reliability is confirmed if the reliability coefficients for all measures exceed 0.70.
   (h) Risk of bias: selective reporting or omission of certain information in scientific studies can lead to a distorted or incomplete representation of the findings.
   (i) Response rate/Recovery rate: for survey or questionnaire.
   (j) Country: the subjects of the study are from
   (k) Academic Discipline: that the study examined if applicable, such as anatomy education, language learning, fashion education etc.
3. Preliminary Testing and Fine-Tuning: The initial data extraction phase entailed piloting the second data extraction sheet using a random selection of three research papers. This preliminary assessment allowed for fine-tuning the extraction sheet, thereby ensuring its clarity, uniformity, and suitability for the task at hand.
4. Procedure of Data Extraction: One reviewer conducted the primary data extraction using the first sheet to categorize the studies based on their distinct features. This categorization was then independently verified by a second reviewer. For the included research articles, the secondary data extraction sheet was utilized, with one reviewer being responsible for the initial extraction of pertinent data.
5. Verification of Data: To maintain accuracy and completeness, a second reviewer independently inspected the data extracted from the research articles. Discrepancies or divergences between the reviewers were addressed via discussion and consensus.
6. Record of Data Gathering Procedure: The complete data collection process was meticulously documented, encompassing the categorization of studies and data extraction from the research papers. This recorded documentation facilitates the systematic review's transparency, reproducibility, and reliability.

3.3.2. *Data summarization*

The findings from individual studies were summarized and integrated using a narrative synthesis approach. The narrative synthesis involved a systematic process of summarizing the key findings from each study, identifying common themes, and integrating the results to provide a comprehensive overview of the factors influencing the adoption and utilization of the Metaverse in educational settings.

3.3.3. *Data presentation*

Data were presented in a structured manner through various formats to facilitate comparison and understanding.

- **Tables:**
  – Tables were used to summarize the characteristics and findings of the included studies.

Table 3
Review papers and systematic reviews papers evaluated for eligibility but not included.

Ref.	Publisher	Paper Type	Publisher Type
Areepong et al. (2022)	IEEE	Review paper	Conference
Rospigliosi (2022)	Taylor and Francis	Review paper	journal
Hwang et al. (2022)	Elsevier	Review paper	journal
S et al. (2023)	MDPI	Review paper	journal
TUTGUN-Ü et al. (2022)	Süleyman Nihat ŞAD	Review paper	journal
Barrá and ez-Herrera (2022)	Asia Pacific Academy of Science Pte	Review paper	journal
Singh et al. (2022)	IGI Global	Review paper	Book chapter
Lin et al. (2022)	Preprints.org	Review paper	conference
Mitra (2023)	DergiPark Akademik	Review paper	journal
Andembubtob et al. (2023)	IGI Global	Review paper	Book chapter
Zhang et al. (2022)	Frontiers Media SA	Review paper	journal
Li and Yu (2022)	Frontiers Media SA	Systematic review	journal
Hidayanto et al. (2022)	IEEE	Systematic review	Conference
George Reyes et al. (2023)	Pixel-Bit	Systematic review	journal
Tlili et al. (2022)	Springer	Systematic review	journal
Han et al. (2023)	MDPI	Systematic review	journal
Zonaphan et al. (2022)	IEEE	Systematic review	conference
Ló et al. (2023)	Universidad de Murcia, Servicio de Publicaciones	Systematic review	journal
Alfaisal et al. (2022)	Springer	Systematic review	journal
Samala et al. (2023)	International Association of Online Engineering	Systematic review	journal
Maheswari et al. (2022)	IEEE	Systematic review	conference
Saritas and Topraklikoglu (2022)	ERIC	Systematic review	journal
Onggirawan et al. (2023)	Elsevier	Systematic review	conference
Topraklıkoğ et al. (2023)	IGI Global	Systematic review	Book chapter
Kaddoura and Al Husseiny (2023)	PeerJ Inc.	Systematic review	journal
De Gagne et al. (2023)	LWW	Umbrella review	journal

- For example, Table 5 provides an overview of the subjects' characteristics of the 31 empirical research studies included in this systematic review.Table. 6
- Table 7 offers additional details regarding the purpose, theoretical model assessed, method, software tools, instrument, and academic discipline examined in these studies.
- Table 6 classifies the factors that impact users' intention to use and embrace the Metaverse in the educational sector into four categories: Confirmed Factors, Debatable Factors, Possible Factors, and Rejected Factors.

● **Figures:**
- Figures were utilized to visually depict the results of the meta-analysis, highlight trends, and illustrate the distribution of studies.
- For instance, the PRISMA 2020 flow diagram (Fig. 2) graphically represents the selection process of the studies included in the review.

● **Narrative Synthesis:**
- A narrative synthesis was provided to contextualize the findings and discuss their implications.

Table 4
Risk of bias and internal reliability in selected studies.

Ref.	Check for Internal Reliability	Risk of Bias
Akour et al. (2022)	Yes, a Cronbach's alpha test was performed, resulting in a reliability coefficient of 0.70.	No risk of bias detected; multiple tests including Harman's single-factor test confirmed bias absence.
Yang et al. (2022)	Yes, reliability confirmed via Cronbach's Alpha and CITC, all above 0.7.	High risk of bias due to non-representative sample and limited demographic applicability.
Ren et al. (2022)	Yes, reliability verified using Cronbach's Alpha and CITC.	High risk of bias from convenience sampling and regional limitations.
Bhavana and Vijayalakshmi (2022)	Yes, high internal consistency with a Cronbach's alpha above 0.931.	Risk of bias due to insufficient demographic data.
Marlen et al. (2023)	Yes, internal reliability checked.	Data exclusion based on statistical limits introduced bias.
Yue (2022)	No check for internal reliability performed.	Significant risk of bias due to selective demographic and geographic sampling.
Burnett et al. (2022)	No check for internal reliability performed.	Limited data collection methods and small sample size contribute to high risk of bias.
Ló et al. (2022)	Yes, reliability supported by Cronbach's alpha and McDonald's Omega.	Bias from non-random participant selection and expert involvement.
Khalil et al. (2023)	Yes, good reliability values for UTAUT constructs reported.	Bias likely due to small sample size and unclear evaluation criteria.
Rachmadtullah et al. (2023)	No check for internal reliability performed.	No evident bias.
Jang et al. (2023)	Yes, internal reliability confirmed.	High risk of bias from limited sample diversity and small sample size.
Teng et al. (2022)	Yes, strong convergent validity and reliability confirmed.	Risk of bias from gender imbalance and limited educational diversity.
Alawadhi et al. (2022)	Yes, high construct reliability confirmed across multiple metrics.	Low risk of bias, well-controlled study design.
Jin et al. (2022)	No check for internal reliability performed.	Bias from limited participant diversity and omitted data.
Wang et al. (2022)	Yes, Cronbach's alpha above 0.7 indicates strong internal reliability.	Risk of bias from small sample size and incomplete data disclosure.
Arpaci et al. (2023)	Yes, various internal consistency metrics reported; all satisfactory.	Potential bias from self-reported data and cross-sectional study design.
Adetayo et al. (2023)	No check for internal reliability performed.	Risk of bias from expert-driven questionnaire modifications.
Gim et al. (2022)	Yes, reliability confirmed with structural equation modeling analysis.	Low risk of bias, thorough validation procedures employed.
Lee et al. (2023)	No check for internal reliability performed.	Geographic and sample selection biases present.
Al-Kfairy et al. (2022)	No check for internal reliability performed.	High risk of bias from limited sample diversity and geographic focus.
Mughal et al. (2022)	No check for internal reliability performed.	High risk of bias from purposeful sampling and lack of private sector representation.
Almarzouqi et al. (2022)	Yes, Cronbach's alpha used for reliability assessment.	Low risk of bias, comprehensive methodological checks performed.
Han (2022)	Yes, high credibility of measurement scales confirmed.	Bias likely from sampling limitations and focus on a specific major.

(continued on next page)

Table 4 (*continued*)

Ref.	Check for Internal Reliability	Risk of Bias
Aburayya et al. (2023)	Yes, Cronbach's alpha used extensively for reliability testing.	High risk of bias from sampling strategy and data analysis limitations.
Salloum et al. (2023)	Yes, Cronbach's alpha values all above 0.7.	Bias from limited sample diversity and method of survey distribution.
Manna (2023)	No check for internal reliability performed.	Bias from inability to collect certain data due to pandemic restrictions.
Issa Ahmad AlSaleem (2023)	Yes, high reliability scores for data collection and analysis.	Bias from limited sample diversity and geographic focus.
Ş et al. (2022)	Yes, Cronbach alpha values consistently high across various factors.	No risk of bias detected; comprehensive data inclusion and analysis.
Suh and Ahn (2022)	Yes, Cronbach's alpha confirms reliability for all major items.	High risk of bias from uneven sample distribution and lack of socio-economic data.
Iwanaga et al. (2023)	No check for internal reliability performed.	High risk of bias from limited participant diversity and geographic focus.
Kim et al. (2022)	Yes, Cronbach's alpha values indicate strong internal reliability.	Risk of bias from limited socio-economic data and small, homogeneous sample.

By presenting the data in these formats, the review ensures clarity and facilitates the interpretation of findings, allowing readers to understand the comprehensive picture of how various factors influence the adoption and utilization of the Metaverse in education.

3.3.4. Synthesis methods

By synthesizing these themes, the study provides a comprehensive understanding of the multifaceted factors that influence the adoption and utilization of the Metaverse in educational settings. This thematic analysis highlights the complex interplay between technological, educational, social, psychological, and institutional factors in shaping users' willingness to embrace innovative educational technologies.

The data synthesis for our systematic review solely involved qualitative approaches, aiming to provide a comprehensive understanding of the factors influencing the adoption and utilization of the Metaverse in educational settings.

Thematic analysis was employed to systematically identify and interpret recurring themes and patterns across the studies included in the review. This process began with a careful coding of the qualitative data extracted from each study. The codes were then organized into broader categories based on their relationship to one another and their relevance to the research objectives.

Each category was further analyzed to identify underlying themes, which were critically examined to understand how they contribute to the broader understanding of Metaverse adoption in education. This thematic synthesis allowed us to capture nuanced insights into the contextual and psychological elements that influence users' willingness to engage with Metaverse technologies. The thematic findings are crucial for outlining the theoretical and practical implications of Metaverse technologies in educational environments, as discussed in subsequent sections of the paper. The thematic analysis identified several key themes, which are elaborated below.

- **Technological Accessibility:** This theme encompasses the ease of access and usability of Metaverse technologies. Factors such as the availability of hardware, internet connectivity, and user-friendly interfaces were critical in influencing adoption rates. Studies highlighted the importance of ensuring that Metaverse platforms are accessible to all users, regardless of their technical expertise or resources.
- **Educational Value:** The perceived educational benefits of using the Metaverse emerged as a significant theme. This includes the enhancement of learning experiences through immersive simulations, interactive content, and the ability to visualize complex concepts. Participants reported higher engagement and motivation when educational content was delivered through Metaverse technologies.
- **Social Interaction:** The role of social interaction within the Metaverse was another prominent theme. The ability to collaborate with peers, engage in group activities, and participate in virtual communities was seen as a major advantage. This social aspect was particularly valued in remote learning environments where physical interaction is limited.
- **Psychological Factors:** Factors such as user attitudes, self-efficacy, and emotional responses to Metaverse technologies were also identified. Positive attitudes towards technology, confidence in using digital tools, and enjoyment of immersive experiences significantly influenced users' willingness to adopt the Metaverse.
- **Privacy and Security:** Concerns about data privacy and security within the Metaverse were recurrent themes. Users expressed the need for robust security measures to protect personal information and ensure safe online interactions. Addressing these concerns was essential for building trust and encouraging adoption.

By focusing on qualitative synthesis, our study was able to explore the depth and complexity of the subject matter, providing a rich narrative that supports the development of theory and offers practical guidance for the implementation of Metaverse technologies in educational settings.

3.3.5. Subgroup and sensitivity analyses

Due to the nature of the data collected and the research questions addressed in this systematic review, subgroup analyses were not performed. The studies included were not sufficiently homogeneous in terms of design or reported outcomes to justify a meaningful subdivision into subgroups that could be systematically compared.

Additionally, sensitivity analyses were not conducted in this review. Typically, such analyses are performed to assess the robustness of the meta-analytical conclusions to various assumptions about the data and methods used. However, since meta-analysis was not part of our synthesis method due to the qualitative focus of our integration, sensitivity analyses were not applicable to our study setup.

3.4. Risk of bias assessment

This subsection evaluates the risk of bias across various studies included in the systematic review, focusing on internal reliability measures and potential biases identified in the study methodologies.

The Risk of Bias Assessment Table 4 evaluates the internal reliability and potential biases across multiple studies concerning the Metaverse and its applications. Most studies, such as those by Akour (Akour et al., 2022) and Gim (Gim et al., 2022), demonstrated a robust approach to ensuring internal reliability, primarily using Cronbach's alpha to confirm the consistency of measurement scales. Despite rigorous internal reliability checks, many studies exhibited a significant risk of bias due to various methodological and sampling issues.

For instance, studies like that of Yang (Yang et al., 2022) and Yue (Yue, 2022) showed high risks of bias because of non-representative samples and limited demographic scopes, focusing excessively on specific populations such as highly educated students or specific geographical areas. Similarly, the study by Jin (Jin et al., 2022) also indicated potential biases due to the homogeneous nature of the participant pool, which consisted only of students from a specific university.

Despite these concerns, all studies, including those with identified risks of bias, were included in the systematic review. This inclusion was

Table 5
Subjects characteristics for empirical research studies.

Ref.	Subjects	Gender	Age	Education Level	Country
Akour et al. (2022)	862	40% male and 60% female	48% between (18 and 29) and 52% above 29.	62% had bachelor's, 32% had master's, and 6% had PhD.	UAE, KSA, and Oman
Yang et al. (2022)	1074	415 male and 659 female		all freshmen and sophomores in college.	China
Ren et al. (2022)	839	292 male and 547 female		all freshmen and sophomores in college.	China
Bhavana and Vijayalakshmi (2022)	597	73.9% male, 26.0% female, and 0.2% other.	34% below 18, 43.4% (18–21), 21.3% (22–25), 8.0% (26–29), and 21.6% (30 and up).	7.4% Diploma, 23.6% Higher Secondary, 46.9% Undergraduate, 18.1% Postgraduate, and 4.0% PhD.	India
Marlen et al. (2023)	35				Indonesia
Yue (2022)	130		under 18 (n = 22,16.9%) 18–30 (n = 54,41.5%),30–40 (n = 35,26.9%),over 40(n = 19,14.6%)	elementary, middle, and higher education institutions	Shenzhen, China
Burnett et al. (2022)	49			undergraduate or postgraduate students at the University of Nottingham.	England
Ló et al. (2022)	362 participants	39.5% men (n = 143) and 60.5% women (n = 219)	Ages between 14 and 16 (Mean = 15.3; SD = 1.226)	3rd year 57.5% and 4th year 42.5% Secondary Education	Spain
Khalil et al. (2023)	325			(n = 315) university students and (n = 10) university teachers	Pakistan
Rachmadtullah et al. (2023)	20			since all the subjects are teachers, it can be inferred that they had bachelor degree	Indonesia
Jang et al. (2023)	38	all female	M = 20.08 years (range: 18–25).	19 first-year, 10 s-year, 6 third-year, and 3 fourth-year	South Korea
Teng et al. (2022)	495	68.9% women.	mostly under 20 or within the age range of 21–30 years	The majority of the subjects were undergraduate students. There were also 9 master's and doctoral students.	China
Alawadhi et al. (2022)	435	53% male and 47% female	72% within the age range of 18 years and 29 years, 28% older than 29	11% held doctoral degrees, 33% had master's degrees, and 56% had bachelor's degrees	UAE
Jin et al. (2022)	18	The instructors were 3 females and 6 males, students were 4 females and 5 males	instructors age(M = 43.56 years old), students age (M = 25.67 years old)	9 instructors,9 students	US
Wang et al. (2022)	275	47.20% male, 52.80% female.	34.18% of the participants were younger than 22 years old, 38.18% were within the age bracket of 22–35 years, 20.00% were between 36 and 50 years old, while 7.64% were older than 50 years.	34.18% had lower than high school education, 49.82% had college education, 22.91% had university education, and 3.27% had postgraduate or above education.	China
Arpaci et al. (2023)	424	57.5% female	The ages ranged between 16 and 33 years (mean ± SD = 23.93 ± 9.49).	71.7% of the participants were university students. 28.3% of them were graduate students holding a bachelor's degree.	Turkey
Adetayo et al. (2023)	1009	59.7% female	74.7% between the ages of 16 and 20		Nigeria
Gim et al. (2022)	535	238 male, 297 female			Korea
Lee et al. (2023)	120			college students	Korea
Al-Kfairy et al. (2022)	84	56% female and 44% male	The bulk of the student participants (76.2%) fell within the age range of 18–22 years. Another 22.6% of the students were aged between 23 and 27 years, with the rest being above the age of 28 years.	undergraduate students	UAE
Mughal et al. (2022)	54			12 teachers, 12 M.Phil./Ph.D. scholars, 6 faculty members, 12 secondary school students, and 12 higher secondary students	Pakistan
Almarzouqi et al. (2022)	1858	55% males, 45% female	49% btween 18 and 29, above 29 comprised 51%	55% held bachelor's degrees, 37% had master's degrees, and 8% possessed doctoral degrees.	UAE.
Han (2022)	200				China
Aburayya et al. (2023)	369	265 female and 104 male	73% of the group was between 18 and 29 years old	79% undergraduates, 16% master's degrees, 4% doctorates, and 1% diplomas.	UAE.
Salloum et al. (2023)	953	Male 58%, females 42%	between 18 and 29 years 76%, older than 29 years 24%	77% BA degree, and 23% MA degree.	Oman
Manna (2023)	7	all female	ages ranged from 25 to 62		Argentina
Issa Ahmad AlSaleem (2023)	50	22 (44%) female and 28 (56%) male	15 (n = 5,10%), 16(n = 26,52%), 17 (n = 19,38%)	high school students	Jordan
Ş et al. (2022)	70	33 male and 37 female		all secondary school mathematics teachers	Türkiye
Suh and Ahn (2022)	336	165 males, 171 females		elementary school students in the fifth and sixth grades.	Korea
Iwanaga et al. (2023)	64				Majority from USA.
Kim et al. (2022)	226	77 males, 149 females		university undergraduate students	South Korea
Di Natale et al. (2024)	324	256 females, 68 males	21.8 ± 2.18 years	undergraduate students	Italy
Nguyen et al. (2024)		39.33% male, 60.67% female	18-25 (64.00%)	(84%) held a bachelor's degree, with 20% possessing a doctoral degree.	Vietnam

(continued on next page)

Table 5 (*continued*)

Ref.	Subjects	Gender	Age	Education Level	Country
Alfaisal et al. (2024)	287			elementary students	UAE
Kalı et al. (2024)	47	All the participants are female students.	Two students are 18 years old or below, while the remaining 45 students' age range varies between 19 and 21 years.	undergraduate students	Turkey

justified due to the novelty of the Metaverse technology and the evolving nature of research in this field. The emerging state of Metaverse applications means that even preliminary findings are valuable for developing a comprehensive understanding of the technology's impacts and potentials. Additionally, the inclusion of these studies aids in highlighting current methodological challenges and guiding future research directions, ensuring a more diverse and robust body of evidence in subsequent investigations.

This assessment highlights the rigorous checks for internal reliability and the varied risk levels of bias across studies. Studies exhibiting a high risk of bias were often due to non-representative samples, lack of diversity in demographics, and methodological shortcomings in data collection and analysis.

4. Results

This section presents a comprehensive overview of the empirical studies included in this systematic review.

4.1. Summary of included studies

Table 5 provides an overview of the subjects' characteristics of the 31 empirical research studies included in this systematic review. Furthermore, Table 7 offers additional details regarding the purpose, theoretical model assessed, method, software tools, instrument, and academic discipline examined in the 31 empirical research studies.

4.2. Key factors influencing the acceptance of metaverse in education

This subsection delves into the significant factors that have been empirically validated to influence the acceptance of Metaverse technologies in educational settings. The findings from various studies underscore the pivotal roles these factors play in shaping user decisions and interactions with this emerging technology. Fig. 6 presents the confirmed factors influencing the adoption of Metaverse technologies in educational settings. Each bar represents a different factor, ordered by the number of empirical studies that support its influence. This visualization highlights the most substantiated factors, with 'Perceived Ease of Use' and 'Perceived Usefulness' being the most supported, indicating their critical role in facilitating user adoption of the Metaverse in education. This ordering helps to prioritize areas for intervention and further research.

4.2.1. Perceived ease of use (PEOU)

Perceived Ease of Use is consistently highlighted as a critical factor in the acceptance of Metaverse applications in education. Studies show that when users perceive a technology as easy to use, they are more likely to embrace and utilize it within educational contexts (Aburayya et al., 2023; Akour et al., 2022; Alawadhi et al., 2022; Almarzouqi et al., 2022; Han, 2022; Manna, 2023; Marlen et al., 2023; Ren et al., 2022; Wang et al., 2022).

4.2.2. Perceived usefulness (PU)

Perceived Usefulness has been identified as a fundamental determinant in the acceptance of educational technologies, including the Metaverse. Users are more inclined to adopt technologies that they perceive as enhancing their educational performance or providing significant value (Aburayya et al., 2023; Akour et al., 2022; Alawadhi et al., 2022; Almarzouqi et al., 2022; Han, 2022; Issa Ahmad AlSaleem, 2023; Khalil et al., 2023; Marlen et al., 2023; Wang et al., 2022).

4.2.3. Social influence (SI)

The impact of Social Influence is profound in educational environments where peer opinions and societal norms can significantly affect individual technology acceptance decisions. This factor is crucial for understanding group dynamics and social pressures that encourage or inhibit the use of Metaverse technologies (Khalil et al., 2023; Wang et al., 2022; Yang et al., 2022).

4.2.4. Perceived complexity

The complexity perceived by users can act as a barrier or facilitator to technology adoption. Simplified and intuitive Metaverse interfaces are favored, reducing cognitive load and increasing acceptance (Akour et al., 2022; Salloum et al., 2023).

4.2.5. Personal Innovativeness

Individuals with high Personal Innovativeness are more likely to adopt and accept Metaverse technologies in educational settings. Their openness to new experiences drives early adoption and influences broader user groups (Akour et al., 2022; Salloum et al., 2023).

4.2.6. User Satisfaction

User Satisfaction directly influences the likelihood of continued use and acceptance of Metaverse technologies. Higher satisfaction correlates with increased adoption rates among educational users (Akour et al., 2022; Almarzouqi et al., 2022).

4.2.7. Performance expectancy (PE)

Performance Expectancy is a predictor of Metaverse technology acceptance, where users anticipate improvements in educational outcomes and efficiencies (Khalil et al., 2023; Yang et al., 2022).

4.2.8. Perceived autonomy

Offering users control and flexibility within the Metaverse significantly affects their acceptance. Technologies that support user autonomy in navigating and interacting with content are more readily adopted (Arpaci et al., 2023; Gim et al., 2022).

4.2.9. Behavioral intention/consumer intention

Behavioral Intention is a strong indicator of whether users will engage with Metaverse technologies. This intention is largely influenced by the aforementioned factors and directly impacts the initial and sustained use of these technologies in educational settings (Kalı et al., 2024; Nguyen et al., 2024).

The synthesis of these factors provides a robust framework for understanding the key drivers behind the acceptance of Metaverse technologies in education. Each factor, supported by empirical evidence, highlights specific areas that educators and technology developers should focus on to enhance the effectiveness and adoption of these innovative educational tools.

4.3. Confirmed, debatable, possible, and Rejected Factors

Table 6 classifies the factors that impact users' intention to use and

Table 6
Factors influencing Users' Intention to Use and Acceptance of Metaverse in Educations.

Table 6 (*continued*)

Confirmed Factors	Debatable Factors	Rejected Factors	Possible Factors
Perceived Ease of Use/Perceived Ease of Use (PEOU)/Easy to Learn (Support: (Akour et al., 2022), (Ren et al., 2022), (Marlen et al., 2023), (Alawadhi et al., 2022), (Wang et al., 2022), (Almarzouqi et al., 2022), (Han, 2022), (Aburayya et al., 2023), (Manna, 2023), (Alfaisal et al., 2024))	Performance Expectancy (PE) (Support: (Yang et al., 2022), (Khalil et al., 2023), (Di Natale et al., 2024), Reject: (Kalı et al., 2024))	Perceived Privacy Risk (Reject: (Wang et al., 2022), (Al-Kfairy et al., 2022))	Perceived Trialability (Support: (Akour et al., 2022))
Perceived Usefulness/Perceived Usefulness (PU)/Perceptions of Educational Value/Perceived Value (Support: (Akour et al., 2022), (Marlen et al., 2023), (Khalil et al., 2023), (Alawadhi et al., 2022), (Wang et al., 2022), (Almarzouqi et al., 2022), (Han, 2022), (Aburayya et al., 2023), (Issa Ahmad AlSaleem, 2023), (Alfaisal et al., 2024))	Effort Expectancy (EE) (Support: (Teng et al., 2022), (Khalil et al., 2023), (Di Natale et al., 2024), Reject: (Yang et al., 2022), (Kalı et al., 2024))	Teaching Model (Reject: (Yue, 2022))	Perceived Observability (Support: (Akour et al., 2022))
Social Influence (SI)/Social Needs/Social Impact (Support: (Yang et al., 2022), (Khalil et al., 2023), (Wang et al., 2022), (Di Natale et al., 2024), (Kalı et al., 2024))	Gender (Support: (Ren et al., 2022), Reject: (Han, 2022))	Mediating Impacts of Dedication and Absorption (Reject: (Jang et al., 2023))	Perceived Compatibility (Support: (Akour et al., 2022))
Perceived Complexity (Support: (Akour et al., 2022), (Salloum et al., 2023))	Perceived Ubiquity (Support: (Aburayya et al., 2023),Reject: (Salloum et al., 2023))	Technology Maturity (Reject: (Wang et al., 2022))	Acceptance of Modern Technology (Support: (Yue, 2022))
Personal Innovativeness/User Innovativeness (Support: (Akour et al., 2022), (Salloum et al., 2023), (Di Natale et al., 2024))	Mobility/Flexibility of Location and Time (Support: (Al-Kfairy et al., 2022), Reject: (Marlen et al., 2023))	Need for Dominance, Achievement and Affiliation (Reject: (Arpaci et al., 2023))	Positive Experience in Virtual Worlds (Support: (Burnett et al., 2022))
Users' Satisfaction/User Satisfaction (US) (Support: (Akour et al., 2022), (Almarzouqi et al., 2022))	Facilitating Conditions (FC) (Support: (Yang et al., 2022), (Di Natale et al., 2024), (Kalı et al., 2024), Reject: (Khalil et al., 2023))	Concerns about Health, Security, Trust, Usability (Reject: (Al-Kfairy et al., 2022))	Self-Efficacy in Practical Class (Support: (Jang et al., 2023))
Perceived Autonomy (Support: (Arpaci et al., 2023), (Gim et al., 2022))		Grade (Reject: (Han, 2022))	Stakeholder Involvement (Support: (Jin et al., 2022))
Behavioral Intention/Consumer Intention (Support: (Nguyen et al., 2024), (Kalı et al., 2024))		Avatars, Attractive Visual Images/Graphics and Interesting Game-based Rules (Reject: (Kim et al., 2022))	Personalized Learning (Support: (Wang et al., 2022))
		Hedonic Motivation (Rejected: (Kalı et al., 2024))	Task Value in Practical Class (Support: (Jang et al., 2023))
		Habit (Rejected: (Kalı et al., 2024))	Situational Teaching (Support: (Wang et al., 2022))
			System Quality (Support: (Gim et al., 2022))
			Competence (Support: (Gim et al., 2022))
			Perceived Innovation (PI) (Support: (Almarzouqi et al., 2022))
			Perceived Benefit (POB) (Support: (Almarzouqi et al., 2022))
			Perceived Cost (PCO) (Support: (Almarzouqi et al., 2022))
			Perceived Trust (PTR) (Support: (Almarzouqi et al., 2022))
			Learning Atmosphere (Support: (Han, 2022))
			Self-management (Support: (Han, 2022))
			Age (Support: (Han, 2022))
			Immersion (Support: (Salloum et al., 2023))
			Imagination (Support: (Salloum et al., 2023))
			Context Awareness (Support: (Salloum et al., 2023))
			Learning Styles (Support: (Di

(continued on next page)

Table 6 (*continued*)

Confirmed Factors	Debatable Factors	Rejected Factors	Possible Factors
			Natale et al., 2024)) Affordances (Support: (Di Natale et al., 2024)) Perceived Value (Support: (Nguyen et al., 2024)) Attitude Towards the Behavior (Support: (Nguyen et al., 2024)) Subjective Norm (Support: (Nguyen et al., 2024)) Perceived Behavioral Control (Support: (Nguyen et al., 2024))

embrace the Metaverse in the educational sector, based on the empirical research studies, into four distinct categories: Confirmed Factors, Debatable Factors, Possible Factors, and Rejected Factors.

1. Confirmed Factors: At least two studies consistently support these factors, indicating their significant influence on adopting and embracing the Metaverse in the educational sector.
2. Debatable Factors: Some studies support these factors, but not others, leading to varying evidence regarding their impact on adopting and using the Metaverse in the educational sector.
3. Possible Factors: A single study supports these factors, suggesting a potential influence on the adoption of the Metaverse in the educational sector. However, further research is needed to confirm their significance.
4. Rejected Factors: One or more studies have tested these factors but found them irrelevant to adopting the Metaverse in education, indicating they do not substantially influence users' intentions.

The results of this systematic review underscore the diverse and multi-dimensional factors influencing the adoption of Metaverse technologies in education. The detailed examination of 31 empirical studies through various methodological lenses reveals that factors such as perceived ease of use, usefulness, and social influence are pivotal. These findings not only enrich our understanding of how educational technologies are accepted but also highlight the dynamic interplay between user characteristics and technological features in educational settings.

5. Discussion

This discussion section seeks to delineate the implications of our findings for theory and practice and outline potential avenues for future research. By analyzing the adoption of Metaverse technologies in educational settings through the lens of Information Systems theories, this study offers insights into the factors that influence user acceptance and practical strategies for implementing these technologies effectively. We aim to bridge the gap between theoretical frameworks and practical applications, guiding educators, policymakers, and researchers. Additionally, we propose directions for future research that could further enhance our understanding and utilization of the Metaverse in education.

5.1. Theoretical implications

This systematic review significantly advances the theoretical understanding of Metaverse adoption within educational settings. By integrating insights from 35 empirical studies, this research deepens our comprehension of how traditional Information Systems theories—namely, the Technology Acceptance Model (TAM), the Unified Theory of Acceptance and Use of Technology (UTAUT), and the Theory of Planned Behavior (TPB)—can be effectively tailored to embrace the distinct and innovative attributes of the Metaverse.

The study robustly confirms that effort expectancy, self-efficacy, and enjoyment are pivotal in shaping users' behavioral intentions. These factors align well with the core constructs of the aforementioned theories, underscoring their enduring relevance in the fast-evolving landscape of digital technologies. This alignment suggests that the basic tenets of technology acceptance continue to apply, even as educational technologies evolve. However, the distinct immersive and interactive capabilities of the Metaverse introduce new variables that traditional models might not fully capture.

For instance, immersion and virtual presence are influential new dimensions in this study, affecting how users perceive and interact with Metaverse environments. These factors necessitate expanding existing theoretical models to better accommodate how these unique features influence user behavior. Immersion can enhance the perceived reality of an experience, thereby increasing engagement and satisfaction, while virtual presence can significantly modify the traditional dynamics of user interaction within digital learning environments.

Therefore, our findings suggest that while the foundational principles of existing information systems theories are applicable, they require significant adaptations to account for the technological nuances introduced by the Metaverse fully. This could involve the development of sub-constructs or entirely new theoretical frameworks that specifically address the complexities introduced by immersive virtual environments. These adaptations would enhance the predictive power of these theories and provide a more nuanced understanding of user behavior in increasingly sophisticated digital realms.

5.2. Practical implications

From a practical standpoint, the findings of this review provide crucial insights for educators, policymakers, and regulatory bodies aiming to implement Metaverse technologies within educational settings effectively. The factors identified in this study that influence adoption, such as self-efficacy and enjoyment, emphasize the importance of creating educational interventions that are engaging and immersive and supportive in helping users become proficient in navigating these novel environments.

For educators, the challenge is integrating Metaverse technologies to enhance learning outcomes while maintaining educational standards. This requires the development of curricula and teaching methods that leverage the unique capabilities of the Metaverse, such as its immersive and interactive features, to foster deeper learning and engagement among students. Educators must also be equipped with the necessary skills and tools to facilitate learning in these virtual environments, which could necessitate ongoing professional development and training.

Policymakers must consider the dynamic and context-dependent nature of technology adoption highlighted by this study. This underscores the need for flexible and adaptive policy frameworks that can effectively respond to the rapidly evolving technological landscape and the diverse needs of educational institutions and their stakeholders. Policies must support innovation in educational technology while ensuring equitable access and addressing ethical considerations, such as data privacy and the potential for digital divide issues.

Regulatory bodies have a critical role in shaping the environment within which these technologies are deployed. They need to establish clear guidelines and standards to manage the implementation of

Table 7
Studies design and characteristics for empirical research studies.

Ref.	Purpose	Model/Framework	Method	Software Tools	Instrument	Academic Discipline
Akour et al. (2022)	explore the perceptions of students in the Gulf area regarding the use of Metaverse systems for educational purposes.	trialability, observability, compatibility, and complexity, users' satisfaction, personal innovativeness, and Technology Acceptance Model (TAM)	two-step deep-learning-based technique of hybrid SEM-ANN.The first stage of analysis was partial least squares structural equation modelling (PLS-SEM)	IBM SPSS Statistics 23 and SmartPLS Version (3.2.7).	survey consisting of 23+ items	
Yang et al. (2022)	assess college students' willingness to utilize Metaverse technology for basketball education.	Unified Theory of Acceptance and Use of Technology 2 (UTAUT2)	Structural Equation Modelling (SEM)	SPSS 26.0 and UTAUT2.	UTAUT2 questionnaire, which was modified and adapted according to the theme of the article.	natural sciences (IPA) in elementary school students grade 3.
Ren et al. (2022)	investigate the factors that influence college students' willingness to adopt Metaverse technology for basketball instruction.	Technology Acceptance Model (TAM)	Structural Equation Modelling (SEM)	AMOS 22.0	survey online using a five-point Likert scale ranging from 1 for strongly disagree to 5 for strongly agree.	basketball learning
Bhavana and Vijayalakshmi (2022)	seeks to verify and evaluate the impact of an Augmented Reality (AR) application on higher education by employing the ARCS model of learning motivation factors, while also examining the positive attributes associated with the use of AR applications to enhance collaboration.	The attention, relevance, confidence, and satisfaction (ARCS) model	Structural Equation Modelling (SEM)	AMOS	questionnaire	mathematics
Marlen et al. (2023)	identify obstacles, analyze the potentials, and propose solutions for the implementation of the Gamelan Metaverse as an alternative tool for interactive music education in modern society.	Technology Acceptance Model 2	Structural Equation Modeling (SEM)	IBM SPSS 26.0 and IBM AMOS software	questionnaire	interactive music education.
Yue (2022)	assess the residents of Shenzhen's confidence level in utilizing Metaverse applications for education and evaluate the extent of their positive influence on the educational domain.	NA	Qualitative Statistical analysis		questionnaire	
Burnett et al. (2022)	comprehend the influence of a virtual world on the learning experiences of university students and provide recommendations on the implications of the findings for higher education practices.	NA	Qualitative Statistical analysis	Open Broadcaster Software (OBS), Mozilla Hubs, and ProQuest Ebook Central.	a mixed method approach was used, including a questionnaire released to all students, a series of interviews with a sample of students, and observations of the students in real-time via video recording of sessions.	Engineering at the University of Nottingham.
Ló et al. (2022)	create and validate an instrument for assessing educational experiences conducted in the Metaverse.	The model used to conduct the study were designed by (Pena Arcila, 2014) and (Tarouco et al., 2013). Additionally, the European Digital Competence Framework was taken as a reference to incorporate the netiquette dimension and the adaptation of the Motivated Strategies for Learning Questionnaire (MSLQ) to Spanish to measure student motivation (Segura-Robles et al., 2021)	Structural Equation Modeling (SEM)	SPSS 25.0 and AMOS 25.0	questionnaire	
Khalil et al. (2023)	determine the intentions of university students to adopt Educational	The Unified Theory of Acceptance and Use of Technology (UTAUT)	Structured Equation Modeling(SEM)	SPSS, AMOS, and NVIVO.	survey questionnaire designed on the basis of a five-point Likert Scale	

(continued on next page)

Table 7 (*continued*)

Ref.	Purpose	Model/Framework	Method	Software Tools	Instrument	Academic Discipline
	Metaverse for their learning purposes.				and interviews to collect data.	
Rachmadtullah et al. (2023)	assess the readiness of teachers in elementary schools to embrace the development of Metaverse Technology as a transformative learning medium, and analyze the benefits of implementing Metaverse Technology as a means to transform learning media in elementary schools.	NA	Descriptive analysis through qualitative research, Bibliometric analysis	NVivo and VOS Viewer.	semi-structured interview.	social studies.
Jang et al. (2023)	examines the effects of class mode on self-efficacy and task value, and investigates the mediating role of dedication and absorption in the relationship between class mode and expectancy-value beliefs.	Expectancy-Value Beliefs	A one-way ANOVA test	SPSS, and SAS procedures	The Motivated Strategies for Learning Questionnaire (MSLQ)	fashion education.
Teng et al. (2022)	investigate the factors influencing students' adoption of the Eduverse in higher educational institutions, and analyze the attitude, behavioral intention, and actual usage of the Eduverse among students.	The Unified Theory of Acceptance and Use of Technology (UTAUT)	Structural equation modeling (SEM)	SPSS 22.0 and Amos 24.0.	survey	
Alawadhi et al. (2022)	examine the perceptions of students within the medical community of the United Arab Emirates (UAE) regarding the use of Metaverse systems in medical training.	adoption properties of personal innovativeness, perceived enjoyment, and Technology Acceptance Model	Structural equation modeling (SEM)	SmartPLS Version (3.2.7)	survey	medical training
Jin et al. (2022)	explores the tensions among various stakeholders in higher education, identifies values and design opportunities present in VR-supported education, and seeks to understand the challenges associated with integrating VR in the classroom.	NA	Qualitative content analysis.	Zoom, Miro, Spatial, and VR headsets.	Semi-structured interviews and participatory design workshops.	
Wang et al. (2022)	explore the factors that influence the usage intention of the Metaverse education application platform, utilizing the PPM (push-pull-mooring) model and the TAM (technology acceptance model) as theoretical frameworks.	Structural equation modeling (SEM) and fsQCA (fuzzy-set qualitative comparativeanalysis)	SmartPLS 3.0	Questionnaire		
Arpaci et al. (2023)	investigates the predictive role of psychological needs in determining the educational sustainability of the Metaverse.	custom model based on psychological needs (i.e. hedonic, motivation, affiliation, dominance, achievement, and autonomy) and educational sustainability	hybrid method integrating covariance-based structural-equation-modeling (CB-SEM) and deep artificial neural network (ANN) model	Google Forms, AMOS 25.0	survey	
Adetayo et al. (2023)	examines the willingness of students in Nigeria to utilize a Metaverse academic library (MAL) if it were to become available.	NA	Descriptive statistics such as frequency counts, percentages, mean and standard deviation scores were used.	not reported	structured questionnaire.	library
Gim et al. (2022)	explores the variables that impact learner satisfaction in VR education within the	Self-Determination,The Information Systems Success	Structural equation modeling (SEM) analysis.	Smart PLS 3.0	survey	

(*continued on next page*)

Table 7 (*continued*)

Ref.	Purpose	Model/Framework	Method	Software Tools	Instrument	Academic Discipline
	Metaverse, with a focus on examining the mediating role of flow theory.	Model and Technology acceptance model(TAM)				
Lee et al. (2023)	examines the feasibility and specific characteristics of a Metaverse-based educational service that has the potential to drive innovation in university education, enabling untact and non-face-to-face interactions in the post-corona era.	NA	Conjoint analysis is statistical technique used in market research to understand how consumers make choices and evaluate the importance of different attributes in products or services.	not reported	survey	
Al-Kfairy et al. (2022)	investigates the motivation factors and obstacles faced by students in utilizing Metaverse-based classrooms.	NA	Qualitative Statistical and thematic analysis	Google Forms and Google Docs.	qualitative survey	
Mughal et al. (2022)	explores the perceptions of research scholars enrolled in education departments of public sector universities regarding the future of education with respect to Metaverse technology.	NA	Content analysis.	not reported	Semi-structured interviews.	
Almarzouqi et al. (2022)	examine the factors that predict user intention to adopt the Metaverse System (UMS) for medical education in the UAE.	Technology Acceptance Model (TAM), Personal innovativeness (PI), Perceived Compatibility (PCO), User Satisfaction (US), Perceived Triability (PTR), and Perceived Observability (POB).	The study uses Weka (ver. 3.8.3) to assess the research models based on various classifiers such as OneR, BayesNet, J48, and Logistics. It also applies PLS-SEM in IS general guidelines and uses the hybrid SEM-ANN method to validate the research hypotheses.	Weka (ver. 3.8.3), SmartPLS version 3.2.7, and IBM SPSS version 23.	questionnaire	medical
Han (2022)	explores the impact of blended learning on law students within the context of the Metaverse concept, seeking to understand how this emerging concept can enhance their learning experiences and knowledge acquisition.	Technology acceptance model (TAM) andUnified Theory of Acceptance and Use of Technology (UTAUT)	Structural equation modeling (SEM),chi-square test, and one-way ANOVA of variables	SmartPls2.0 and SPSS24.	online questionnaire.	law
Aburayya et al. (2023)	explore the elements that encourage adoption of the Metaverse system among individuals in the United Arab Emirates (UAE) and develop a conceptual model that illustrates crucial elements based on the researcher's understanding to investigate the existing knowledge gap.	Technology Acceptance Model (TAM)	partial least squares structural equation modeling(PLS-SEM)	Smart PLS V.3.2.7 and Weka	questionnaire	medical
Salloum et al. (2023)	explores the adoption of Metaverse technology in academic institutions. The proposed conceptual model in this paper incorporates factors such as innovativeness, context awareness, perceived enjoyment, ubiquity, complexity, and value.	The method of analysis used in this study is Partial Least Squares-Structural Equation Modeling (PLS-SEM).	SmartPLS Version 3.2.7 and IBM SPSS 23.0	survey using a Likert scale that includes five categories which represent five scores.		
Manna (2023)	explores educators' perceptions regarding the design and implementation of mobile Augmented	NA	Reflexive Thematic Analysis (RTA)	Metaverse (https://studio.gometa.io)	Semi-structured pre- and post-implementation interviews.	foreign language education

(continued on next page)

Table 7 (*continued*)

Ref.	Purpose	Model/Framework	Method	Software Tools	Instrument	Academic Discipline
	Reality (AR) for teaching Italian as a foreign language (TIFL), while highlighting the potential benefits and challenges associated with its utilization in language education.					
Issa Ahmad AlSaleem (2023)	aims to assess the perceptions of young Jordanian learners regarding the use of Metaverse platforms in language learning, while examining the effects of technological changes on their language learning processes.	NA	mixed-method approach, combining both qualitative and quantitative methods. The quantitative data collected in this study were analyzed using the SPSS 24 statistical program. The qualitative data were analyzed through the content analysis method.	SPSS 24	The researcher used a literature review to develop the interview questionnaire. The quantitative part of the study involved the use of an opinion survey. A structured interview form was also used for the qualitative part.	language learning.
Ş et al. (2022)	determine the knowledge, attitudes, and awareness scores of secondary school mathematics teachers regarding the concept of Metaverse, and aims to gain insights into their perspectives on the concept and utilization of Metaverse in mathematics education.	NA	convergent parallel mixed-method approach, which involves the simultaneous collection of quantitative and qualitative data. Descriptive statistics, *t*-test for independent samples, and content analysis were employed to analyze the data.	SPSS 24.0, Google Forms	The study used a mixed method, with a scanning pattern used in the quantitative dimension and a case study used in the qualitative dimension.	mathematics.
Suh and Ahn (2022)	examines the experiences of elementary school students in using the Metaverse, to determine its suitability for learner-centered constructivist education in the post-pandemic era.	Extended TAM model	Structural equation modeling (SEM)		A survey.	
Iwanaga et al. (2023)	explores the utilization of a Metaverse in anatomy education and surveys attendees of the 2022 annual meeting of the American Association of Clinical Anatomists (AACA) to gain insights into implementing a Metaverse in the clinical realm.	NA	The authors conducted a survey and used descriptive statistics to analyze the results.	not reported	The survey was distributed to the attendees at registration, and once they completed the survey, they returned their anonymous responses to the reception desk.	anatomy education.
Kim et al. (2022)	identify the predictiveness of perceived ease to use (PEU), perceived usefulness (PU), perceived enjoyment (PE), and frequency of experience (FE) on the intention to use (IU) a Metaverse-based learning environment.	Extended TAM model	Multiple regression analysis	SPSS 22.0 and Google survey forms.	questionnaire	
Di Natale et al. (2024)	Predict students' intention to adopt IVR for learning. They further explored the role that different individual factors, have on their attitudes toward IVR.	The Unified Theory of Acceptance and Use of Technology (UTAUT), Learning styles(CE, RO, AC, and AE), Affordances Perceptions, Personal Innovativeness	Hierarchical multiple regression analysis	Qualtrics	survey	
Nguyen et al. (2024)	Investigate the adoption of met-averse education in Ho Chi Minh City, Vietnam.	Theory of Planned Behavior (TPB)	Partial least squares structural equation modeling.	G*Power version 3.1	survey	

(*continued on next page*)

Table 7 (*continued*)

Ref.	Purpose	Model/Framework	Method	Software Tools	Instrument	Academic Discipline
Alfaisal et al. (2024)	Aims to scrutinize the perceptions of elementary students towards the metaverse system (MS).	The expanded TAM model	Partial Least Squares Structural Equation Modelling (PLS-SEM) technique.	SmartPLS Version (3.2.7)	survey	
Kalı et al. (2024)	The research aims to investigate the behaviors of students receiving anatomy education in the metaverse environment.	The unified theory of acceptance and use of technology-2 (UTAUT2)	The partial least squares structural equation modeling.	SmartPLS 3.3.9	survey	Medical

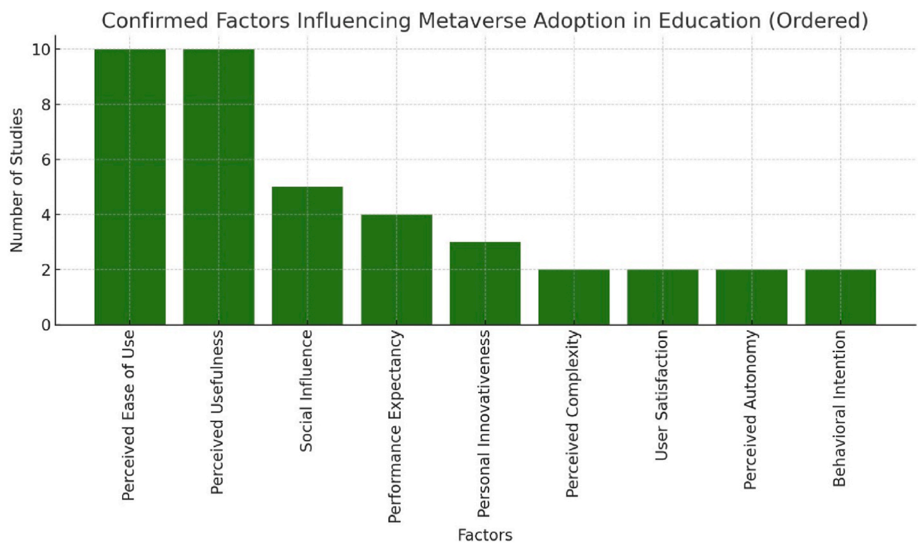

Fig. 6. Ordered Confirmed Factors Influencing Metaverse Adoption in Education, showing the relative number of studies supporting each factor.

Metaverse technologies, ensuring they meet educational objectives without compromising student safety or privacy. Regulations should encourage transparency and accountability in using these technologies, particularly in collecting, using, and protecting data.

Furthermore, recognizing challenges such as the need for robust technological infrastructure and overcoming user resistance suggests that targeted strategies must be developed. For instance, investment in technological infrastructure is essential to support the high demands of Metaverse platforms, which require significant bandwidth and processing power. Addressing user resistance involves technical support and cultural change initiatives within educational institutions to foster an environment that is open to digital innovation.

Integrating Metaverse technologies into mainstream education should be approached with a strategic partnership among educators, policymakers, and regulatory bodies. Such collaboration can ensure that deploying these technologies is thoughtful, addressing potential risks while maximizing educational benefits. This holistic approach will be key to successfully leveraging the Metaverse to transform educational landscapes.

5.3. Future research directions

This review synthesizes the current understanding of Metaverse technologies in educational settings and highlights critical areas for future research, setting a comprehensive agenda for advancing this field.

Firstly, there is a pressing need for longitudinal studies investigating the adoption and impact of Metaverse technologies over time. Such studies are invaluable because they allow researchers to observe how these technologies' perceptions and usage patterns evolve as users become more accustomed to their functionalities and potential. Longitudinal research can provide deeper insights into the sustainability of technology adoption, the long-term educational benefits, and the ongoing challenges that may not be apparent in short-term studies. These insights are crucial for developing strategies that support sustained use and optimize the educational impacts of Metaverse technologies.

Secondly, further research should delve into the impact of cultural and contextual factors on adopting the Metaverse. The current body of literature is predominantly centered around specific geographic and cultural contexts, which may not universally represent global perspectives and experiences with these technologies. By expanding the geographic scope of research, scholars can uncover valuable insights into how different cultural contexts influence the perception, effectiveness, and acceptance of Metaverse technologies. This expanded understanding could help customize these technologies to meet diverse educational needs and preferences, enhancing global accessibility and relevance.

Moreover, developing new theoretical models tailored to the unique attributes of immersive technologies like the Metaverse is essential. Current Information Systems theories provide a solid foundation but may not fully capture the complexities and novel experiences associated with immersive virtual environments. Developing new models or significantly adapting existing ones to incorporate spatial presence, virtual collaboration, and immersive interaction could significantly advance our theoretical understanding. These models would enrich academic discourse and provide educators and technology developers with practical frameworks for designing and implementing Metaverse technologies more effectively.

Such theoretical advancements should also consider the psychological and social aspects of learning in immersive environments.

Understanding how these environments affect learners' cognitive load, motivation, and social interaction could inform the design of more effective educational experiences.

Lastly, integrating insights from interdisciplinary research, incorporating fields such as psychology, sociology, and human-computer interaction, could enhance the design and functionality of educational Metaverse applications. Researchers and practitioners can create more engaging, intuitive, and beneficial educational tools by understanding the human elements of technology use.

In summary, by addressing these future research directions, the academic community can better support integrating Metaverse technologies into educational systems, ensuring they are effective, equitable, and tuned to the diverse needs of learners worldwide.

5.4. Ethical and privacy considerations

Implementing the Metaverse in educational settings involves a sophisticated array of technological components and considerations, each of which plays a crucial role in successfully integrating this advanced technology. Key components include hardware, software, and networking infrastructure. Essential hardware for the Metaverse includes high-performance computers and virtual reality (VR) headsets necessary to handle high-resolution graphics and rapid data processing. Software components are central to creating immersive VR and AR environments, encompassing development tools for interactive content and systems for managing educational interactions. Robust networking infrastructure is also crucial, as it supports the real-time, continuous data transmission required by the Metaverse; technologies such as 5G are particularly important because they provide the necessary bandwidth and low latency (Park et al., 2022).

Beyond these core components, several additional technological considerations must be addressed to ensure the Metaverse's effectiveness and safety in educational contexts. Security is a paramount concern, involving encryption to safeguard personal data, secure data transmissions, and protection against unauthorized access. Privacy protections are equally important, particularly for compliance with global data protection regulations and ensuring the safety of minor users. Interoperability is another critical factor, allowing for seamless integration across various platforms and devices, essential for creating a cohesive user experience (Al-kfairy et al., 2023).

Usability and accessibility are foundational to the Metaverse's educational success, necessitating user-friendly interfaces that accommodate users with varying levels of technical proficiency. This includes simplified navigation, intuitive controls, and features that can be customized to enhance the educational experience. Scalability is also a significant consideration, as educational institutions may need to expand their Metaverse implementations to accommodate different class sizes or a growing user base. Finally, the sustainability of the Metaverse should be considered, including the environmental impact of the required computing equipment and the long-term costs associated with updates, maintenance, and training (Al-Kfairy et al., 2022, 2024).

By addressing these technological components and considerations, educational institutions can develop a Metaverse environment that is engaging and educational but also secure, private, interoperable, and sustainable. Such a comprehensive approach ensures that integrating the Metaverse into educational settings maximizes learning outcomes and provides immersive experiences that could redefine educational standards and practices.

6. Conclusion

This study articulates a methodical review and quantitative synthesis of the elements impacting user inclination towards the adoption and utilization of the Metaverse within the pedagogical milieu.

6.1. Summary of findings

A total of 35 empirical analyses, leveraging Information Systems theoretical models including but not limited to TAM, UTAUT, TPB, and their subsequent extensions were subjected to scrutiny in an attempt to decipher the underpinning variables. The quantitative synthesis unearthed the extent to which factors on an individual, technological, and environmental scale impinged on users' inclination towards and adoption of the Metaverse within an educational context. A series of moderating effects of these factors were identified, insinuating the context-dependent and dynamic nature of users' Metaverse interaction in the education arena. The conclusions drawn from this research add a new dimension to the extant literature on the educational Metaverse by providing a meticulous and stringent synthesis of the prevailing body of knowledge. The practical ramifications of these findings are significant for educators, policymakers, and scholars striving to optimize the usage of the Metaverse within educational spheres.

However, the review is subject to certain restrictions that warrant consideration. The evaluation exclusively incorporated studies adhering to Information Systems theories such as TAM, UTAUT, TPB, and their extensions. Although these theories are extensively employed in this context, there exists a possibility of other pertinent theoretical frameworks that this review might have overlooked. The analysis also only included studies documented in English, potentially resulting in the omission of relevant research recorded in different languages. Lastly, the review was restricted to studies providing quantitative data, hence possibly disregarding significant qualitative studies.

6.2. Implications for stakeholders

This systematic review of factors influencing the adoption of the Metaverse in education has several key implications for various stakeholders involved in educational technology. These implications are intended to guide educators, policymakers, technology developers, and researchers in optimizing and strategizing the deployment of Metaverse technologies within educational frameworks.

6.2.1. Educators and academic institutions

For educators and academic institutions, the findings highlight the importance of integrating user-friendly and useful Metaverse applications into the curriculum. Understanding the role of perceived ease of use and usefulness suggests that training sessions and initial hands-on experiences could be vital in increasing adoption rates. Furthermore, educators are encouraged to consider the social dynamics and cultural contexts of their student bodies when integrating these technologies, as social influence and cultural relevance significantly affect acceptance and effective usage.

6.2.2. Policymakers and educational planners

Policymakers should note the critical role of technological infrastructure and the broader environmental factors that facilitate or hinder the adoption of innovative technologies like the Metaverse. Investments in robust digital infrastructure, especially in underprivileged regions, could democratize access to advanced educational tools. Additionally, developing guidelines that ensure privacy, security, and ethical use of Metaverse technologies should be a priority to address potential risks and ethical concerns.

6.2.3. Technology developers and industry partners

Developers of Metaverse platforms must focus on designing interfaces that are not only easy to use but also align with educational goals to ensure their relevance and usefulness. The emphasis on user satisfaction and performance expectancy as key drivers of adoption should guide the development phases, ensuring that these platforms are capable of meeting diverse educational needs and are accessible to users with varying abilities.

6.2.4. Researchers in educational technology

The identified gaps in current research provide a roadmap for future studies. Researchers are urged to explore longitudinal impacts, diverse cultural contexts, and the integration of interdisciplinary approaches to provide deeper insights into the cognitive, social, and emotional aspects of learning in immersive environments. Empirical validation of theoretical models tailored to immersive learning environments also remains a crucial area needing attention.

6.2.5. Investors and granting agencies

For those funding educational technology ventures and research, the review underlines the importance of supporting projects that address the significant gaps in current literature, particularly those that expand the scope of research to include non-English language studies, qualitative data, and studies from diverse geographical and cultural settings. Funding initiatives that focus on inclusivity and accessibility of technology will also be critical in ensuring that the benefits of the Metaverse can be experienced widely across different socio-economic groups.

In conclusion, the successful integration of Metaverse technologies in education relies on a collaborative effort among all stakeholders to address both the opportunities and challenges presented by this innovative technology. By understanding and acting on these implications, stakeholders can effectively harness the potential of the Metaverse to enhance educational outcomes and foster an inclusive, engaging, and supportive learning environment.

6.3. Final thoughts and future outlook

The systematic review of Metaverse technologies in educational settings has revealed several critical gaps in the current research landscape. These gaps underscore the need for further investigations that can deepen our understanding and enhance the effective integration of these technologies. The identified research gaps are as follows.

1. **Longitudinal and Developmental Insights**: There is a notable absence of longitudinal studies that track the adoption and impact of Metaverse technologies over extended periods. Current research predominantly focuses on short-term effects and initial adoption stages, leaving a significant gap in understanding how these technologies influence learning and engagement over time and how users adapt to and integrate these tools into regular educational practice.
2. **Cultural and Contextual Diversity**: Most existing studies are concentrated in specific geographic regions, primarily Western and East Asian contexts. This concentration results in a lack of data from diverse cultural and educational settings, such as developing countries, where technological infrastructure and educational methodologies might differ significantly. Research exploring these environments is crucial for developing a global understanding of the Metaverse's educational potential and limitations.
3. **Interdisciplinary Approaches**: While current studies effectively apply Information Systems theories, there is a gap in research that integrates perspectives from other relevant disciplines, such as cognitive psychology, educational science, and sociology. Such interdisciplinary approaches are essential to comprehensively assess the cognitive, social, and psychological impacts of learning in immersive virtual environments.
4. **Empirical Validation of Theoretical Models**: There is a scarcity of studies that empirically test new or adapted theoretical models that address the unique attributes of immersive and interactive Metaverse technologies. Most research relies on existing frameworks, which may not fully capture the complexities of user engagement and learning dynamics in these highly interactive virtual spaces.
5. **Accessibility and Inclusivity**: Research on the accessibility and inclusivity of Metaverse technologies is limited. Studies need to address how these technologies can be designed and implemented to support users with disabilities and those from various socio-economic backgrounds. This research gap highlights the need for inclusive design principles that ensure equitable access to educational opportunities within the Metaverse.
6. **Ethical and Privacy Concerns**: Although the Metaverse offers promising educational opportunities, insufficient research addresses the ethical implications and privacy concerns associated with its use in education. These include issues related to data security, user surveillance, and the potential for misuse of immersive technologies.
7. **Impact on Educational Outcomes**: Finally, there is a lack of conclusive evidence regarding the impact of Metaverse technologies on traditional educational outcomes such as critical thinking, problem-solving skills, and academic achievement. More rigorous, methodologically sound research is needed to ascertain these impacts, critical for justifying the integration of Metaverse technologies into mainstream educational curricula.

Addressing these research gaps will enhance the theoretical understanding of Metaverse technologies and guide effective, ethical, and inclusive practical implementations. By filling these gaps, the academic and educational communities can better harness the Metaverse's potential to transform educational practices and outcomes globally.

Future research directions, bearing in mind these limitations, might encompass systematic reviews and quantitative syntheses that include studies utilizing alternate theoretical frameworks, non-English language studies, and qualitative data reports. Future studies may also consider deploying mixed-methods approaches to delve into the factors influencing users' intention to adopt and use the Metaverse in an educational setting, thereby amalgamating quantitative and qualitative data. Additionally, future research could probe into the potential of emerging technological advancements like artificial intelligence and blockchain in enhancing user experience within the educational Metaverse.

Source of support

This work was supported by the Zayed University RIF grant activity code R22085.

CRediT authorship contribution statement

Mousa Al-kfairy: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Soha Ahmed:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization. **Ashraf Khalil:** Writing – review & editing, Writing – original draft, Validation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix 1. Detailed Search Strategy

This systematic review adheres to the updated guidelines provided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Page et al., 2021).

Inclusion Criteria

In our systematic review, studies were selected based on stringent eligibility criteria adhering to the PICO framework. Table 2 outlines our eligibility criteria in a structured format, aligned with the well-recognized PICO model, which includes Population, Intervention, Comparator, Outcome, and an additional component for Study Characteristics.

Data Source and Method of Search

A systematic search approach was utilized to identify pertinent studies on the employment of the Metaverse in education. The search was carried out in multiple electronic databases, comprising Scopus, Google Scholar, DBLP: Computer Science Bibliography, The International Prospective Register of Systematic Reviews (PROSPERO), Cochrane Database of Systematic Reviews (CDSR), and Scientific Electronic Library Online (Scielo). These databases were chosen for their comprehensive coverage, relevance to the field, and accessibility. Scopus and Google Scholar provide extensive multidisciplinary coverage and include peer-reviewed journal articles, conference papers, and other scholarly literature. DBLP specializes in computer science, ensuring the inclusion of technical and research-focused studies. PROSPERO, CDSR, and Scielo are recognized for their contributions to systematic reviews and health-related research, offering high-quality, peer-reviewed articles that support the rigorous analysis required for a systematic review. Search terms were formulated using controlled vocabularies and keywords. The search strategy consisted of two groups of words: (1) the method and the body area of interest (Metaverse); and (2) the factor of interest (education, learning, teaching). This resulted in the following search strings: "Metaverse and education" (Topic) OR "Metaverse and learning" (Topic) OR "Metaverse and teaching" (Topic). The search strings were tailored to each database's specific syntax and capabilities. The exact search terms and keywords used (including any Boolean operators) and the number of documents retrieved from each database are presented in Table 1. It should be noted that no filters were applied. The data collection process involved utilizing various Python code snippets to enhance efficiency and streamline the acquisition of paper titles and abstracts. Python code was employed to download search results from Google Scholar and format the obtained results from DBLP using Google Colab. Python code was also utilized to identify and eliminate duplicate papers. The code development involved leveraging ChatGPT to assist in automating tasks such as acquiring titles and abstracts, removing duplicates, and formatting data.

Data from Scopus and Web of Science did not require additional formatting or processing and were directly downloaded as Excel spreadsheets using the available options. However, the results were manually inputted into a Google Sheet due to the limited availability of data from sources such as Scielo, CDSR, and PROSPERO.

The adoption of Python code snippets facilitated the efficient collection and processing of paper titles and abstracts. While some databases provided readily useable data, others necessitated the implementation of customized code for data manipulation and extraction. Combining automated procedures and manual input ensured comprehensive coverage of the literature for the systematic review.

Selection Process

Initial Screening: Title and Abstract Assessment

An extensive search of the seven electronic databases followed the pre-established search strategy. The records obtained were imported into Google Sheets, and duplicates were eliminated. Two trained and calibrated reviewers (MAK and SGA) independently assessed the titles and abstracts for each record. The records were categorized into the following groups using predefined inclusion and exclusion criteria.

- Potentially eligible: Full-text access will be obtained for further evaluation.
- Exclude: Records that did not satisfy the inclusion criteria.
- Unclear: Records that required additional investigation for eligibility.

In case of disagreement, a discussion reached a consensus on which articles to assess full-text. If needed, a third researcher was consulted to make the final decision (AFK).

Secondary Screening: Full-Text Evaluation

The full texts of potentially eligible studies identified in the initial round were accessed and assessed by the same reviewers (MAK and SGA) who independently screened the titles and abstracts and skimmed through the entire articles. This resulted in the exclusion of additional articles. Then, one reviewer (SGA) fully evaluated all potentially eligible studies. Conflicts or ambiguities concerning the eligibility of studies were clarified and resolved via dialogue.

References

Aburayya, A., Salloum, S., Alderbashi, K., Shwedeh, F., Shaalan, Y., Alfaisal, R., Malaka, S., & Shaalan, K. (2023). Sem-machine learning-based model for perusing the adoption of metaverse in higher education in uae. *International Journal of Data and Network Science, 7*(2), 667–676.

Adetayo, A. J., Adekunmisi, S. R., Abata-Ebire, B. D., & Adekunmisi, A. A. (2023). Metaverse academic library: Would it be patronized? Digital library. *Perspectives, 39* (2), 229–240.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*(2), 179–211.

Akour, I. A., Al-Maroof, R. S., Alfaisal, R., & Salloum, S. A. (2022). A conceptual framework for determining metaverse adoption in higher institutions of gulf area: An empirical study using hybrid sem-ann approach. *Computers and Education: Artificial Intelligence, 3*, Article 100052.

Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of things: A survey on enabling technologies, protocols, and applications. *IEEE communications surveys & tutorials, 17*(4), 2347–2376.

Al-Kfairy, M., Al-Fandi, O., Alema, M., & Altaee, M. (2022). Motivation and hurdles for the student adoption of metaverse-based classroom: A qualitative study. In *2022 international conference on computer and applications (ICCA)* (pp. 1–5). IEEE.

Al-kfairy, M., Alomari, A., Al-Bashayreh, M., Alfandi, O., Altaee, M., & Tubishat, M. (2023). A review of the factors influencing users' perception of metaverse security and trust. In *2023 tenth international conference on social networks analysis, management and security (SNAMS)* (pp. 1–6) (IEEE).

Al-Kfairy, M., Alomari, A., Al-Bashayreh, M., Alfandi, O., & Tubishat, M. (2024). Unveiling the metaverse: A survey of user perceptions and the impact of usability, social influence and interoperability. *Heliyon, 10*(10), Article e31413.

Alawadhi, M., Alhumaid, K., Almarzooqi, S., Aljasmi, S., Aburayya, A., Salloum, S. A., & Almesmari, W. (2022). Factors affecting medical students' acceptance of the metaverse system in medical training in the United Arab Emirates. *South Eastern European Journal of Public Health (SEEJPH)*.

Alfaisal, R., Hashim, H., & Azizan, U. H. (2022). Metaverse system adoption in education: A systematic literature review. *Journal of Computers in Education*, 1–45.

Alfaisal, R., Hashim, H., & Azizan, U. H. (2024). Exploring the adoption of the metaverse system among elementary students. *Journal of Advanced Research in Applied Sciences and Engineering Technology, 40*(2), 117–126.

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.

Andembubtob, D. R., Keikhosrokiani, P., & Abdullah, N. L. (2023). The critical success factors of metaverse adoption in education: From the consumer behaviour perspective. In *Handbook of research on consumer behavioral analytics in Metaverse and the adoption of a virtual world* (pp. 171–203). IGI Global, ???

Anderson, T. (2008). *The theory and practice of online learning*. athabasca university press.

Areepong, T., Nilsook, P., & Wannapiroon, P. (2022). A study of a metaverse interdisciplinary learning community. In *2022 research, invention, and innovation congress: Innovative electricals and electronics (RI2C)* (pp. 290–296). IEEE.

Arpaci, I., & Bahari, M. (2023). 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, 1–13*.

Bakhri, S., & Sofyan, M. A. (2022). Prototype curriculum: Opportunities and challenges of inclusive schools in implementing education for all in the metaverse era. *Muslim Education Review, 1*(2), 157–177.

Barráez-Herrera, D. (2022). Metaverse in a virtual education context. *Metaverse, 3*(1), 1–9.

Bartle, R. A. (2004). *Designing virtual worlds*. New Riders.

Battal, A., & Taşdelen, A. (2022). The use of virtual worlds in the field of education: A bibliometric study. *Participatory Educational Research, 10*(1), 408–423.

Bhavana, S., & Vijayalakshmi, V. (2022). Ai-based metaverse technologies advancement impact on higher education learners. *WSEAS Transactions on Systems, 21*, 178–184.

Bicen, H., & Adedoyin, O. B. (2022). Bibliometric analysis of studies on metaverse in education. *International Conference on Virtual Learning, 17*, 179–192.
Bower, M. (2019). Technology-mediated learning theory. *British Journal of Educational Technology, 50*(3), 1035–1048.
Burnett, G. E., Harvey, C., & Kay, R. (2022). Bringing the metaverse to higher education: Engaging university students in virtual worlds. In *Methodologies and use cases on extended reality for training and education* (pp. 48–72). IGI Global, ???
Castronova, E. (2005). *Synthetic worlds: The business and culture of online games*. Chicago, IL: University of Chicago Press.
De Filippi, P., & Wright, A. (2018). *Blockchain and the law: The rule of code*. Harvard University Press.
De Gagne, J. C., Randall, P. S., Rushton, S., Park, H. K., Cho, E., Yamane, S. S., & Jung, D. (2023). The use of metaverse in nursing education: An umbrella review. *Nurse Educator, 48*(3), 73–78.
Dearing, J. W., & Cox, J. G. (2018). Diffusion of innovations theory, principles, and practice. *Health Affairs, 37*(2), 183–190.
Dede, C. (2009). Immersive interfaces for engagement and learning. *Science, 323*(5910), 66–69.
Di Natale, A. F., Repetto, C., Costantini, G., Riva, G., Bricolo, E., & Villani, D. (2024). Learning in the metaverse: Are university students willing to learn in immersive virtual reality? *Cyberpsychology, Behavior, and Social Networking, 27*(1), 28–36.
Dignum, V. (2019). *Responsible artificial intelligence: How to develop and use AI in a responsible way, 2156*. Springer. ???
Egger, J., Gall, M., Wallner, J., Boechat, P., Hann, A., Li, X., Chen, X., & Schmalstieg, D. (2017). Htc vive mevislab integration via openvr for medical applications. *PLoS One, 12*(3), Article 0173972.
Gülen, S., Dönmez, İ., & Şahin, İ. (2022). Stem education in metaverse environment: Challenges and opportunities. *Journal of STEAM Education, 5*(2), 100–103.
George Reyes, C. E., Ramírez Montoya, M. S., & López Caudana, E. O. (2023). Imbrication of the metaverse in the complexity of education 4.0: Approach from an analysis of the literature. *Revista de Medios y Educación, 66*, 199–237.
Gim, G., Bae, H., & Kang, S. (2022). Metaverse learning: The relationship among quality of vr-based education, self-determination, and learner satisfaction. In *2022 IEEE/ACIS 7th international conference on big data, cloud computing, and data science (BCD)* (pp. 279–284) (IEEE).
Han, B. (2022). Research on the deciding factors of blended learning effect of law students under the background of metaverse. In *2022 3rd international conference on artificial intelligence and education (IC-icaie 2022)* (pp. 1144–1153). Atlantis Press.
Han, J., Liu, G., & Gao, Y. (2023). Learners in the metaverse: A systematic review on the use of roblox in learning. *Education Sciences, 13*(3), 296.
Harley, D. (2020). Palmer luckey and the rise of contemporary virtual reality. *Convergence, 26*(5–6), 1144–1158.
Hidayanto, A. N., Prabowo, H., et al. (2022). Discipline, impact, and challenges of virtual reality in higher education: A systematic literature review. In *2022 international conference on information management and technology (ICIMTech)* (pp. 476–481) (IEEE).
Hwang, G.-J., & Chien, S.-Y. (2022). Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective. *Computers and Education: Artificial Intelligence, 3*, Article 100082.
Issa Ahmad AlSaleem, B. (2023). The efficiency of metaverse platforms in language learning based on jordanian young learners' perceptions. *Arab World English Journal, 14*.
Iwanaga, J., Muo, E. C., Tabira, Y., Watanabe, K., Tubbs, S. J., D'Antoni, A. V., Rajaram-Gilkes, M., Loukas, M., Khalil, M. K., & Tubbs, R. S. (2023). Who really needs a metaverse in anatomy education? A review with preliminary survey results. *Clinical Anatomy, 36*(1), 77–82.
Jang, J., Kim, J., et al. (2023). Exploring the impact of avatar customization in metaverse: The role of the class mode on task engagement and expectancy-value beliefs for fashion education. *Mobile Information Systems, 2023*.
Jin, Q., Liu, Y., Yarosh, S., Han, B., & Qian, F. (2022). How will vr enter university classrooms? Multi-stakeholders investigation of vr in higher education. In *Proceedings of the 2022 CHI conference on human factors in computing systems* (pp. 1–17).
Johnson, N. (2006). *The educational potential of second life*. Digital Union Showcase.
Kaddoura, S., & Al Husseiny, F. (2023). The rising trend of metaverse in education: Challenges, opportunities, and ethical considerations. *PeerJ Computer Science, 9*, 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.
Khalil, A., Haqdad, A., & Sultana, N. (2023). Educational metaverse for teaching and learning in higher education of Pakistan. *Journal of Positive School Psychology*, 1183–1198.
Kim, K., Yang, E., & Ryu, J. (2022). Work-in-progress—the effect of students' perceptions on intention to use metaverse learning environment in higher education. In *2022 8th international conference of the immersive learning research network (iLRN)* (pp. 1–3). IEEE.
Kraus, S., Kumar, S., Lim, W. M., Kaur, J., Sharma, A., & Schiavone, F. (2023). From moon landing to metaverse: Tracing the evolution of technological forecasting and social change. *Technological Forecasting and Social Change, 189*, Article 122381. https://doi.org/10.1016/j.techfore.2023.122381
Krueger, M. W., Gionfriddo, T., & Hinrichsen, K. (1985). Videoplace—an artificial reality. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 35–40).
López Belmonte, J., Pozo-Sánchez, S., Moreno-Guerrero, A.-J., & Lampropoulos, G. (2023). Metaverse in education: A systematic review. *Distance Education Magazine (RED), 23*(73).
López-Belmonte, J., Pozo-Sánchez, S., Lampropoulos, G., & Moreno-Guerrero, A.-J. (2022). Design and validation of a questionnaire for the evaluation of educational experiences in the metaverse in Spanish students (metaedu). *Heliyon, 8*(11), Article 11364.
Lee, J., & Jang, S. (2023). Metaverse-based education service adoption and preference study using conjoint analysis. In *2023 international conference on computing, networking and communications (ICNC)* (pp. 273–277) (IEEE).
Li, M., & Yu, Z. (2022). A systematic review on the metaverse-based blended English learning. *Frontiers in Psychology, 13*.
Lin, H., Wan, S., Gan, W., Chen, J., & Chao, H.-C. (2022). *Metaverse in education: Vision, opportunities, and challenges*. arXiv preprint arXiv:2211.14951.
Lippman, A. (1980). Movie-maps: An application of the optical videodisc to computer graphics. *Acm Siggraph Computer Graphics, 14*(3), 32–42.
Maheswari, D., Ndruru, F. B. F., Rejeki, D. S., Moniaga, J. V., & Jabar, B. A. (2022). Systematic literature review on the usage of iot in the metaverse to support the education system. In *2022 5th international conference on information and communications technology (ICOIACT)* (pp. 307–310) (IEEE).
Manna, M. (2023). Teachers as augmented reality designers: A study on Italian as a foreign language–teacher perceptions. *International Journal of Mobile and Blended Learning, 15*(2), 1–16.
Marangunić, N., & Granić, A. (2015). Technology acceptance model: A literature review from 1986 to 2013. *Universal Access in the Information Society, 14*, 81–95.
Marlen, D. R., Nastiti, P., Primasari, C. H., Wibisono, Y. P., & Negara, J. G. P. (2023). Analysis of the effect of gamelan metaverse on acceptance of music education methods using technology acceptance model 2. *JISAMAR (Journal of Information System, Applied, Management, Accounting and Research), 7*(1), 22–34.
Mitra, S. (2023). Metaverse: A potential virtual-physical ecosystem for innovative blended education and training. *Journal of Metaverse, 3*(1), 66–72.
Mughal, M. Y., Andleeb, N., Khurram, A. F. A., Ali, M. Y., Aslam, M. S., & Saleem, M. N. (2022). Perceptions of teaching-learning force about metaverse for education: A qualitative study. *Journal of Positive School Psychology, 6*(9), 1738–1745.
Mystakidis, S. (2022). *Metaverse. Encyclopedia, 2*(1), 486–497.
Nguyen, B.-H. T., Dang, T.-Q., Nguyen, L.-T., & Tran, T.-T. T. (2024). Are we ready for education in metaverse? Pls-sem analysis. *Edelweiss Applied Science and Technology, 8*(2), 73–83.
Noor, A. K. (2016). The hololens revolution. *Mechanical Engineering, 138*(10), 30–35.
Onggirawan, C. A., Kho, J. M., Kartiwa, A. P., Gunawan, A. A., et al. (2023). Systematic literature review: The adaptation of distance learning process during the covid-19 pandemic using virtual educational spaces in metaverse. *Procedia Computer Science, 216*, 274–283.
P, & Rosenberg, M. (2001). *e-learning: Strategies for delivering knowledge in the digital age*. New York: McGrow-Hill.
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., et al. (2021). The prisma 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, 372*.
Park, S.-M., & Kim, Y.-G. (2022). A metaverse: Taxonomy, components, applications, and open challenges. *IEEE Access, 10*, 4209–4251.
Pena Arcila, J. B. (2014). Metaverses for the master degree iberoamerican in education in virtual environments. *Etic net-revista cientifica electronica de educacion y comunicacion en la sociedad del conocimiento, 14*(2), 227–248.
Rachmadtullah, R., Setiawan, B., Wasesa, A. J. A., & Wicaksono, J. W. (2023). Elementary school teachers' perceptions of the potential of metaverse technology as a transformation of interactive learning media in Indonesia. *International Journal of Innovative Research and Scientific Studies, 6*(1), 128–136.
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*.
Rospigliosi, P.a. (2022). *Adopting the metaverse for learning environments means more use of deep learning artificial intelligence: This presents challenges and problems*. Taylor & Francis.
Ruwodo, V., Pinomaa, A., Vesisenaho, M., Ntinda, M., & Sutinen, E. (2022). Enhancing software engineering education in africa through a metaversity. In *2022 IEEE frontiers in education conference (FIE)* (pp. 1–8) (IEEE).
Sá, M. J., & Serpa, S. (2023). Metaverse as a learning environment: Some considerations. *Sustainability, 15*(3), 2186.
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), 5257.
Samala, A. D., Bojic, L., Indarta, Y., Tsoy, D., Denden, M., Tas, N., Dewi, I. P., et al. (2023). Metaverse technologies in education: A systematic literature review using prisma. *International Journal of Emerging Technologies in Learning, 18*(5).
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.
Schroeder, R., Huxor, A., & Smith, A. (2001). Activeworlds: Geography and social interaction in virtual reality. *Futures, 33*(7), 569–587.
Segura-Robles, A., Moreno-Guerrero, A.-J., Parra-González, M.-E., & López-Belmonte, J. (2021). Adaptation and validation of the motivated strategies for learning questionnaire for Spanish adolescents. European Journal of Investigation in Health. *Psychology and Education, 11*(1), 142–153.

Serrano, R., Morillo, P., Casas, S., & Cruz-Neira, C. (2022). An empirical evaluation of two natural hand interaction systems in augmented reality. *Multimedia Tools and Applications, 81*(22), 31657–31683.
Sharples, M., Taylo, J., & Vavoula, G. (2007). A theory of learning for the mobile age. In R. Andrews, & C. Haythornthwaite (Eds.), *In the sage handbook of elearning research*. London, UK: SAGE Publications.
Singh, J., Malhotra, M., & Sharma, N. (2022). Metaverse in education: An overview. Applying metalytics to measure customer. *Experience in the Metaverse*, 135–142.
Suh, W., & Ahn, S. (2022). Utilizing the metaverse for learner-centered constructivist education in the post-pandemic era: An analysis of elementary school students. *Journal of Intelligence, 10*(1), 17.
Sutherland, I. E. (1968). A head-mounted three dimensional display. In *Proceedings of the december 9-11* (pp. 757–764), 1968, Fall Joint Computer Conference, Part I.
Tamilmani, K., Rana, N. P., Wamba, S. F., & Dwivedi, R. (2021). The extended unified theory of acceptance and use of technology (utaut2): A systematic literature review and theory evaluation. *International Journal of Information Management, 57*, Article 102269.
Tarouco, L., Gorziza, B., Corrêa, Y., Amaral, É. M., & Müller, T. (2013). Virtual laboratory for teaching calculus: An immersive experience. In *2013 IEEE global engineering education conference (EDUCON)* (pp. 774–781) (IEEE).
Taylor, T. L. (2009). *Play between worlds: Exploring online game culture*. MIT press.
Teng, Z., Cai, Y., Gao, Y., Zhang, X., & Li, X. (2022). Factors affecting learners' adoption of an educational metaverse platform: An empirical study based on an extended utaut model. *Mobile Information Systems, 2022*.
Tlili, A., Huang, R., Shehata, B., Liu, D., Zhao, J., Metwally, A. H. S., Wang, H., Denden, M., Bozkurt, A., Lee, L.-H., et al. (2022). Is metaverse in education a blessing or a curse: A combined content and bibliometric analysis. *Smart Learning Environments, 9*(1), 1–31.
Topraklıkoğlu, K., & Öztürk, G. (2023). The metaverse and mathematics education: A literature review. *Shaping the Future of Online Learning: Education in the Metaverse*, 250–266.
Tutgun-Ünal, A., & Tarhan, N. (2022). Metaverse awareness and generation to transform education. *International Journal of Aquatic Research and Education, 8*(1), 64–73.
Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 425–478*.
Wang, G., & Shin, C. (2022). Influencing factors of usage intention of metaverse education application platform: Empirical evidence based on ppm and tam models. *Sustainability, 14*(24), Article 17037.
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 10562.
Yue, K. (2022). Breaking down the barrier between teachers and students by using metaverse technology in education: Based on a survey and analysis of shenzhen city, China. In *2022 13th international conference on E-education, E-business, E-management, and E-learning (IC4E)* (pp. 40–44).
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*.
Zonaphan, L., Northus, K., Wijaya, J., Achmad, S., & Sutoyo, R. (2022). Metaverse as a future of education: A systematic review. *2022 8th International HCI and UX Conference in Indonesia (CHIuXiD), 1*, 77–81 (IEEE).