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Potential to use metaverse for future teaching and learning

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Abstract

Metaverse, a virtual shared space integrating augmented reality and virtual reality technologies, is often hailed as the "Internet of the future" for its potential to revolutionize online communication, collaboration, learning, and work. However, despite its promising strategic and business applications, there is a dearth of empirical evidence for evaluating its educational value. This qualitative study examined the impact of Metaverse on teaching and learning by examining its advantages and challenges. The outcomes highlight Metaverse's remarkable potential for personalized and adaptive learning thanks to its immersive and interactive capabilities. An analysis of the existing literature suggests that Metaverse can create engaging learning experiences in which students can explore tailored virtual environments and interact within them. Semi-structured in-depth interviews were conducted to confirm the perception of metaverse-based education among students, educators, and program administrators, who view it as an innovative and effective educational delivery method. Several barriers require attention to ensure the successful integration of Metaverse in education, such as network connectivity, reliability, standardization and certification, organizational readiness, and the specialized skills necessary to leverage Metaverse's potential. This study offers a comprehensive understanding of Metaverse's potential, limitations, and critical factors contributing to its education success. By providing immersive and interactive learning experiences tailored to individual student needs, Metaverse holds the power to revolutionize teaching and learning. However, addressing challenges related to interoperability and the need for more evidence on its efficacy requires further research and development efforts. The significance of this study hinges on the continued exploration of Metaverse to enhance educational experiences, offering a novel and innovative approach to teaching and learning.

Keywords Metaverse · Metaverse for teaching and learning · Virtual reality · Augmented reality

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1 Introduction

The Metaverse is a virtual space created by the convergence of technologies such as augmented reality and persistent virtual spaces with the internet. It is a potential platform for various applications, including gaming, education, social networking, and e-commerce (Bolger, 2021; S. M. Park and Kim, 2022b). Some proponents of Metaverse envision it as a fully immersive and interactive virtual world that will eventually replace the physical world as the dominant platform for human interaction and commerce. Thus, creating a unified global "marketplace" in which people from all over the world can come together and share information, trade goods, and services, develop new forms of entertainment, and collaborate on projects without having to travel or be present in the exact physical location (Mystakidis, 2022). This is an exciting prospect for people limited by their physical location or lack of resources. It would give them the same opportunities as those in more affluent areas. With the help of digital tools and the dedication of tech giants, Metaverse is becoming a highly intricate and immersive experience, allowing users to live a virtual life (Bolger, 2021). As a result, virtual and augmented reality devices can take users to a virtual world that enables them to do the same activities as in the real world without commuting or facing geographical or cultural obstacles (Mystakidis, 2022). However, there are also concerns about the implications of such a large-scale virtual world, particularly regarding safety and security (Kye et al., 2021; Onu & Mbohwa, 2021b).

Questions have been raised about the potential for abuse of this virtual world, including privacy issues, censorship, exploitation of users, and cyberbullying (Falchuk et al., 2018). These are all valid and important questions that need to be addressed if this global virtual world is to be a safe and secure space for users. As with any new technology, risks will always be considered, and potential problems must be addressed to ensure users' safety and protect the virtual world's integrity (Onu & Mbohwa, 2021a). As the use of virtual and augmented reality technologies continues to grow, the potential of metaverse for teaching and learning has gained increasing attention (Han & Noh, 2021). This presents an excellent opportunity for educators to use Metaverse as an educational tool, providing students with an immersive and engaging learning environment that can be tailored to their individual needs. While there are many advantages of using Metaverse for teaching, several security and privacy issues must be considered when implementing it in the classroom. Further research is required to understand its potential and limitations (Kanematsu et al., 2014). Careful consideration must be given to the protocols for data management and user safety within Metaverse to ensure a safe and secure environment. In addition to the technical security concerns, educators must consider the ethical implications of teaching in a virtual environment, such as maintaining a respectful learning environment.

1.1 Innovation in education

The continuous evolution of educational tools and technology has profoundly impacted education, bringing about significant changes and improvements. In knowledge acquisition and application, tutoring has emerged as a vital component of univer-

sity success, offering a competitive edge to learners. However, it is crucial to consider the specific conditions under which research is conducted and the psychological and social aspects of the subject matter to enhance learning outcomes. Furthermore, in Metaverse, cultural values and technology are interwoven, and technology can significantly impact how cultural values are transmitted and communication technologies are developed. As Morris (2012) explains, cultural values are a set of norms and principles that guide people's behavior and responses to various situations (Morris et al., 2012). Therefore, it is imperative to incorporate values and technology into education to ensure the successful transmission of culture.

Educational pedagogy is a highly specialized area of study, and the introduction of technological advancements has led to periodic changes (Lam et al., 2021). One significant development has been integrating social media into the educational system, initially developed as a Web 2.0 technology (Tao et al., 2021). Social media has diverse educational uses, such as supporting lessons and enabling teachers and students to interact outside the classroom, thus transforming the perception of educational pedagogy. It is vital to recognize that the use of technology in education requires a thoughtful approach that aligns with cultural values. Educators can ensure that technology promotes positive values and beliefs by incorporating cultural values into the design and implementation of technological tools (Antoniou, 2021; Jaffer, 2010). This approach can help build a culture of respect and inclusivity within educational environments, ultimately benefiting the transmission of culture across generations.

The pedagogical structure is a crucial consideration when designing metaverse platforms for education. This concept has existed since ancient Greece and remains a fundamental component of learning-teaching and child education. Pedagogy encompasses students' goals, the knowledge clusters (content) that help them achieve these goals, the methods, and techniques for acquiring the content, and measurement and evaluation. The term "pedagogy" has been used to describe education from ancient times until today.

1.2 Education and the metaverse intersect

The coronavirus pandemic has tremendously impacted education worldwide, forcing teachers and students to transition to a distant learning methodology in 2020. Technology has ensured educational continuity is still possible despite widespread lockdowns. With the advent of Metaverse, there is an opportunity to create an entirely new educational ecosystem. The immersive and interactive nature of metaverse environments can engage students in ways that traditional classroom settings cannot (B.-H. Lee and Park, 2021). Students can explore and interact with complex concepts fun and engagingly, which can help them better understand and retain information. Additionally, Metaverse offers the ability to create personalized learning experiences (Han & Noh, 2021). Educators can design customized learning paths for each student based on their needs and learning styles. This can help to ensure that each student receives the support and guidance they need to succeed. In this new educational ecosystem, school teachers will no longer solely supervise learning and teaching processes. Instead, technological and digital equipment will facilitate and enhance the

learning process in metaverse environments (Son et al., 2022). By embracing this innovative approach to education, we can create a dynamic and engaging learning experience that prepares students for the future.

Over time, there have been many instances that have been characterized as having metaverse-like characteristics. These include technologies that were part of the Metaverse and those that had something to do with its creation, investment, or development (Table 1). In the coming years, we expect to see further advancements in this field as more businesses and developers focus on creating the Metaverse. The advancements in Metaverse technology and tools have drastically enhanced the capabilities of educators to provide more engaging, immersive learning experiences for their students, which has been found to have a positive effect on student motivation. This has been a great boon for education, as it has allowed educators to support their students better, both pedagogically and technologically.

Contrary to popular belief, Metaverse is much more popular than VR or AR (Park & Kim, 2022a). It is distinct from conventional VR or AR due to three defining features: "shared," "persistent," and "decentralized." Metaverse provides users with unparalleled engagement and immersion, going beyond the solitary experiences offered by VR or AR. Unlike these technologies, Metaverse allows users to seamlessly return to their previous activities and continue shaping the environment and content for their leisure, as illustrated in Fig. 1.

This unique feature enables a more captivating and engaging experience for users, who can actively participate in and influence Metaverse over time. For example, in a multiuser virtual reality system such as VRChat and Second Life, people can interact with one another using different identities. However, a metaverse is distinguished by its ability to provide a persistent reality where users can engage in activities, including socializing, education, and commercial enterprises (Min & Cai, 2022). Metaverse offers excellent potential due to its advances in virtualization, high-speed communications, artificial intelligence, and computers. Nonetheless, its integration into the classroom also presents potential issues such as addiction, ethics, and security that should be discussed in greater depth; otherwise, Metaverse could be a source of harm ('metaworse') rather than benefit.

This study aims to examine Metaverse for teaching and learning and identify its advantages and challenges in education. The primary research question that guides this study is: What is the potential of Metaverse for teaching and learning, and what are the consequences of using it in education? This question is significant because it can inform the development and implementation of Metaverse as an educational platform and provide insights into the potential and limitations of this technology for teaching and learning. For the scope and nature of this research and the limited knowledge of implementing Metaverse in education, the qualitative research design approach combining literature review and case study interview was employed. This methodology was deemed valuable for gaining an in-depth understanding of the progress, potential, and implication of using Metaverse for teaching and learning, which is still in its infancy. This paper is structured as follows: the introduction (Sect. 1) is followed by Sect. 2, which defines 'metaverse' and a taxonomy of Metaverse with emphasis on its role in education. Section 3 looks at the research methodology, and Sect. 4 presents the study's results. Section 5 considers the implications for research,

Table 1 A timeline of developments with increasing similarities to the metaverse concept, from earliest to most recent

Year	Innovation	Description
1974	Maze War	Maze War is a first-person shooter game often credited as one of the first examples of a multiplayer virtual world. It was developed by Steve Colley, Howard Palmer, and Greg Thompson at the NASA Ames Research Center in California. (Barton, 2019)
1985	Lucasfilm's Habitat	Habitat was a massively multiplayer online role-playing game (MMORPG) developed by Lucasfilm Games for the Commodore 64 home computer. It was one of the first online virtual worlds to offer a persistent environment where players could interact with each other and with non-player characters (NPCs). (Dede, 1995; Hughes & Moshell, 1997; Morningstar & Farmer, 1970)
1991	WorldsAway	WorldsAway was a graphical virtual world developed by Fujitsu for the CompuServe network. It allowed users to create avatars, interact with each other, and explore a shared digital space. (Neal, 1997a, b)
1992	MUDs and MOOs	Multiuser Dungeons (MUDs) and Multiuser Object-Oriented environments (MOOs) were text-based virtual worlds that allowed multiple users to interact and explore a shared digital space. They were popular among computer science students and early Internet users. (Cook & Stanley, 1997; Tomek, 2000)
1993	Doom	Doom is a first-person shooter game that popularized networked multiplayer gaming. It allowed players to connect over the Internet and engage in virtual combat in a shared digital space. (Crogan, 2003; Mizsei Ward, 2018)
1995	AlphaWorld	AlphaWorld was a virtual world developed by Active Worlds that allowed users to create virtual spaces and interact with other users in real-time. It was one of the first 3D virtual worlds and was popular among early Internet enthusiasts. (Corbit, 2002; Dodge, 2001; Huxor, 2001; Ryan, 2004; Tatum, 2000)
1997	Ultima Online	Ultima Online was a multiplayer online role-playing game (MMORPG) developed by Origin Systems. It was one of the first MMORPGs to offer a persistent digital world where players could interact with each other and with NPCs. (Simpson, 2000; Young, 2006)
1998	EverQuest	EverQuest was a multiplayer online role-playing game (MMORPG) developed by Sony Online Entertainment. It was one of the first MMORPGs to achieve mainstream success, significantly impacting the genre's development. (Chappell et al., 2006; Klastrup, 2009)
2002	There	A 3D virtual world developed by There, Inc. allowed users to create their avatars, interact with each other, and explore a shared digital space. It was popular among early adopters of virtual world technology. (Ward, 2015)
2003	s Life	Second Life was a massively multiplayer online game that allowed users to create avatars and explore a virtual world, with a focus on user-generated content. It was one of the most popular virtual worlds of the early 2000s and significantly impacted the development of virtual world technology. ("Creat. Second Lives," 2011; Kieger, 2010; Ondrejka, 2008)
2006	Kaneva	Kaneva was a 3D virtual world that allowed users to create their avatars, interact with each other, and explore a shared digital space. It was popular among casual gamers and strongly emphasized socialization and community-building. (Ward, 2015)
2007	Google Lively	Google Lively was a 3D virtual world developed by Google that allowed users to create their avatars (Huvila, 2015)

Table 1 (continued)

Year	Innovation	Description
2008	OpenSimulator	OpenSimulator is an open-source platform for creating virtual worlds compatible with Second Life. It allows users to create their virtual worlds, design their avatars, and interact with each other in real-time. (Arai, 2019; Che et al., 2011; Kim & Ke, 2017; Lesko & Hollingsworth, 2013)
2012	Oculus Rift	Oculus Rift is a virtual reality headset that Oculus VR developed. It allowed users to experience virtual worlds fully immersively and significantly impacted the development of virtual reality technology. (Chessa et al., 2019; Farahani et al., 2016)
2013	High Fidelity	High Fidelity is a virtual reality platform founded by Philip Rosedale, the creator of Second Life. It allowed users to create and explore virtual worlds in real-time and was notable for its use of blockchain technology. (Li et al., 2022; Montrey & Shultz, 2020)
2014	Sansar	Sansar was a virtual world platform developed by Linden Lab, the creator of Second Life. It allowed users to create their own virtual spaces, design their avatars, and interact with each other in real-time. (Gawlik-Kobylinska & MacIejewski, 2019; Johnson, 2017)
2017	VRChat	VRChat is a social virtual reality platform allowing users to create avatars and interact in a shared virtual space. It gained popularity on YouTube and Twitch and has been used for virtual events and conferences. (Lang, 2020; Saffo et al., 2021; VRChat, 2021)
2018	Decentraland	Decentraland is a blockchain-based virtual world that allows users to buy, sell, and build on virtual land using cryptocurrency. It was one of the first virtual worlds to use blockchain technology for digital ownership and was notable for its emphasis on user-generated content. (Dowling, 2022; Goanta, 2020)
2021	Roblox	Roblox is a massively multiplayer online game platform that allows users to create their games and virtual worlds. It has become popular among children and young people and has been used for virtual events and concerts. (Knapp, 2018; Meier et al., 2020; Mustaf et al., 2020; S. M. Park and Kim, 2022b; Rospigliosi, 2022)
2019	Facebook Horizon	Facebook Horizon is a social virtual reality platform developed by Facebook. It allows users to create their virtual worlds, interact with each other in real-time, and participate in virtual events and games. The platform is currently in beta testing. (Epstein, 2019; Wang, 2020)
2021	Nvidia Omniverse	Nvidia Omniverse is a virtual collaboration platform that allows users to work together on 3D designs and simulations in real-time. It supports a range of different software applications and is designed to be used by professionals in industries such as architecture, engineering, and entertainment. (Hummel & van Kooten, 2019; Liu et al., 2022)
2022	Epic Games MetaHuman Creator	Epic Games MetaHuman Creator is a tool that allows developers to create high-quality, photorealistic 3D character models. It is designed to be used in various applications, including video games and virtual worlds, and is intended to make it easier and more accessible to create realistic human characters. (Fang et al., 2021)

Fig. 1 Metaverse Feature

practice, limitations, and suggestions for future research. Finally, Sect. 6 serves as the conclusion.

2 Definition and classification of metaverse based on its potential

Metaverse is a revolutionary advancement in Internet technology. It is a portmanteau of the words "meta" and "universe," with "meta" signifying "beyond" and "universe" indicating "the whole world" (Sparkes, 2021). The concept of Metaverse is believed to have originated in the early 1990s, following the works of Neal Stephenson and, subsequently, William Gibson's novel Idoru (Dell et al., 1992; Farnell, 1998). Since then, various other virtual worlds have been developed, with an increasing number of individuals becoming involved in the Metaverse. Different researchers have provided various definitions of Metaverse. For example, some have defined it as a virtual reality space that extends beyond a passive gaming experience into interactive social and economic spheres (Kye et al., 2021), while others have defined it as a collective virtual shared space that is immersive and interactive and can be accessed through a variety of devices, such as video game software, virtual reality devices, and the internet (X. Zhang et al., 2022b) (Ravenscraft, 2022) (Sparkes, 2021). For the sake of this study, we define metaverse as: an immersive and interactive collective virtual shared space that combines elements of augmented reality, virtual reality, and the internet. It extends beyond gaming, enabling interactive social, economic, and educational experiences. Accessed through various devices and technologies, it merges physical and digital realms, fostering collaboration, personalized interactions, and transformative possibilities for communication and learning. While there is no universally agreed upon classification, researchers have proposed classifications based on metaverse use, with an emphasis on the potential of Metaverse for unique educational possibilities. The following section discusses the classification based on the use of a metaverse for teaching and learning.

2.1 Social metaverse

Virtual worlds such as Second Life and the Matrix were early pioneers of the Metaverse, although they have gained much more popularity and usage. These virtual environments are primarily used for social activities like online chatting, forums, and other forms of interaction (Falchuk et al., 2018). These social metaverses are often more immersive than traditional chat rooms, providing users with a more realistic experience and a greater sense of presence (Duan et al., 2021; Kwon, 2021). Many social metaverses offer virtual goods, such as virtual clothing and currency, which players can purchase and use. Additionally, these virtual environments often provide tools for creative expression, allowing users to create their own stories and artwork (S. Park & Kang, 2021).

2.2 Business metaverse

This virtual world is primarily used for commercial aspects, such as virtual trade shows, virtual offices, and virtual stores. It allows users to conduct business transactions within a secure environment (Seok, 2021). Despite the potential for abuse and exploitation, businesses can benefit from the convenience of working transactions and interacting with customers in a safe virtual environment (Hollensen et al., 2022). By taking the necessary steps to ensure a secure virtual world, businesses can take advantage of this new technology's benefits without worrying about its potential risks. They must put in place the appropriate security measures to protect their data and users from potential hackers, viruses, or other malicious activity and to ensure the safety of their customers' data (Tan & Salo, 2021). Businesses must ensure that their staff is adequately trained and informed on the technology they use and its potential risks to safeguard against any misuse of the virtual world and the security of their customers' data, thus creating and maintaining a safe and secure online environment for all. (Bian et al., 2022).

2.3 Gaming metaverse

This virtual world is primarily used for gaming, such as massively multiplayer online games (MMOGs) like World of Warcraft. These virtual worlds also come with their concerns, such as the potential for game addiction, the impact of in-game purchases and microtransactions on players' wallets, and the potential for cheating or other forms of game exploitation. In addition, MMOGs can be susceptible to cyberattacks, such as distributed denial of service (DDoS) attacks, which can disrupt the entire gaming experience. The creators of virtual worlds must implement security measures to protect users, such as data encryption, two-factor authentication, and comprehensive fraud prevention measures, to preserve the gaming metaverse as a safe, secure, and enjoyable environment for users (Baía Reis & Ashmore, 2022). More recently, the blockchain industry has adopted the term to refer to an open, distributed, and persistent virtual world built on blockchain technology (Zhang et al., 2022a). This virtual world comprises digital assets, such as tokens and digital objects, stored and exchanged on a blockchain (Vidal-Tomás, 2022). The concept of a blockchain-based

Metaverse has become increasingly popular, particularly in the gaming industry, as it provides a secure platform for users to own and trade digital assets.

2.4 Educational metaverse

This type of virtual world is primarily used for education, such as virtual classrooms, training simulations, and virtual labs (Kye et al., 2021). Educational metaverse environments also allow users to collaborate on projects, discuss and share ideas, access resources from around the world and interact in a virtual setting (Akour et al., 2022). While educational metaverses have the potential to create a new and more dynamic learning environment, they require a certain level of oversight to ensure they are safe and secure for students and educators alike. The use of Metaverse for teaching and learning has gained increasing attention in recent years as virtual and augmented reality technologies have become more widely available (Lee et al., 2022; Tian, 2022). Several studies have investigated the potential of the Metaverse for education and identified a range of advantages and challenges associated with its use (Akour et al., 2022; Díaz et al., 2020; Park & Kim, 2022a). It's worth noting that the technology of Metaverse is relatively new, and it's not yet widely adopted in most countries, including several developing countries and emerging economies. The use of virtual and augmented reality technology, including mixed reality, 3D gaming, and holographic technology, is growing in popularity as technology becomes more accessible and affordable.

1) Virtual Reality (VR): VR technology creates an immersive, computer-generated experience that simulates a natural or imagined environment (Tian, 2022). Users interact with the virtual environment using specialized equipment like VR headsets. They can look around, move and interact with the virtual world as if physically present. VR has many applications, including gaming, education, and training (Ulaş, 2015). It is used in fields such as medicine, military, and architecture to simulate real-world scenarios and provide interactive learning experiences, allowing users to gain knowledge and skills in a safe, controlled environment (Chen & Zhang, 2022; Lee et al., 2022).
2) Augmented Reality (AR): AR is a technology that enhances the user's perception of the real world by overlaying digital information on the user's view of the natural world (Avila-Garzon et al., 2021). This can be achieved through various devices like smartphones, tablets, or specialized AR headsets. AR can be used for multiple applications, including gaming, education, and training (Tian, 2022). It has been applied in marketing, design, and healthcare to provide interactive and informative experiences. It can provide contextual information, simulations, and interactive 3D models in education and training, allowing users to learn and practice in a more immersive and engaging way (George Reyes, 2020; Hanid et al., 2020).
3) Mixed Reality (MR): MR combines virtual and augmented reality to seamlessly blend the real and virtual worlds (Gerup et al., 2020). It is achieved through specialized headsets or other devices that can track the user's movements and position in the real world and adjust the virtual environment accordingly. The result

is an immersive experience in which the virtual and real objects co-exist and interact in real time. MR has many applications, including gaming, education, training, design, and manufacturing (Frost et al., 2020; Kounlaxay & Kim, 2020). It allows users to interact with virtual objects in a real-world context, providing a more realistic and engaging experience. It can be used for training, remote collaboration, and virtual prototyping (Birt & Cowling, 2017).

4) 3D gaming and Extended Reality (XR): 3D gaming and XR are immersive technologies (Christou et al., 2022) that can be achieved through VR, AR, MR technologies, and traditional 2D gaming platforms. These technologies allow players to experience the game world more realistically and engagingly, with the ability to move around and interact with the environment, providing a more immersive gaming experience (Anastasiou et al., 2020). 3D games can be played on various platforms, such as consoles, PCs, and mobile devices, and can be used for educational and training purposes (Tashev, 2019). Technology such as XR, when constructed correctly, can boost learning productivity, which is a difficult task with traditional methods. Some XR characteristics can benefit educational settings: Immersion: XR can create a sense of depth and space, allowing users to view 3D content (e.g., objects) as if standing in the same room. Interactivity: XR allows for user-initiated reactions and activities, enabling users to interact actively with their digital environment. Invisibility: XR uses realistic 3D imaging and combines digital and physical elements, making it possible to observe phenomena invisible to the human eye, such as alternating through the years or tiny particles.
5) Holographic technology: Holographic technology is a form of 3D imaging that uses laser technology to create a hologram, a three-dimensional image that appears floating in space (Christou et al., 2022). This technology can be used for gaming, education, and advertising applications. Holographic technology can create interactive displays and immersive visual experiences in gaming, allowing players to interact with the game more realistically and engagingly (Paredes & Vázquez, 2020). In education, holographic technology can create 3D models, interactive simulations, and visual aids to enhance learning and make it more engaging. In advertising, holographic displays can create attention-grabbing, realistic, and memorable experiences (Evgenovych Ph.D. et al., 2019). The technology has also been used in other fields, such as medicine, engineering, and art, to create 3D models and simulations, allowing users to visualize and interact with the objects more realistically (Campos et al., 2013; Shuguang & Lin, 2020).

One example of a company using Metaverse is Immersive Education, which creates virtual worlds and simulations for classrooms. The platform of the Immersive Education Initiative allows students to interact with 3D simulations and virtual environments, such as historic sites and scientific labs, and attend virtual classes and meetings with teachers and classmates (Pricer, 2010). The company partners with several universities and schools, including Boston College, Duke University, and the Massachusetts Institute of Technology. Another example is Virtual Futures, an organization that uses VR and AR to enhance students' educational experiences. They use the technology to simulate real-world scenarios, allowing students to explore

and experiment with concepts in a safe, immersive, and engaging environment (Scott-Stevenson, 2019). They have worked with institutions such as Imperial College London, the University of East London, and the University of Sussex. Recently, Microsoft's Mesh platform has promoted ways to allow users to interact with each other and digital objects in a shared virtual space using mixed-reality devices such as HoloLens and VR headsets. Overall, the "metaverse" is a digital ecosystem and a platform for developing high-level skills that allow for collecting, organizing, analyzing, and sharing data from various sources. The convergence of digital data, real-world analytics, and human expertise enables the efficient creation, exchange, and utilization of knowledge across multiple dimensions of space and time, providing a competitive advantage and opportunities for co-creation.

3 Methodology

A literature review methodically examines existing research on a specific topic. It evaluates and synthesizes previous studies' arguments and findings, emphasizing rigor and completeness (Taylor et al., 2010). The goal is to create a balanced and objective analysis of different viewpoints, building upon previous scholars' work on Metaverse's potential for teaching and learning. Literature analysis is considered an effective tool for academics to identify and understand topics of relevance to practitioners. In addition to a literature review, qualitative interviews can also be used as a data source for research (Marrone & Hammerle, 2017). Cross-case in-depth interview: This process involves interviewing a wide range of individuals who have experienced a particular phenomenon in different ways and at varying intensity levels. This process aims to create a holistic picture of the phenomenon and gain insight into its contributing factors. Researchers can gather valuable insights and perspectives by interviewing experts with experience and knowledge about the topic (Myers & Newman, 2007). This can be particularly useful when access to the members of an organization or institution is not possible (Ryan, 2012). Thus, used to gain knowledge of the consequences of using Metaverse in education.

Different techniques for conducting qualitative interviews exist, such as structured, unstructured, semi-structured, or group. In this research, the results of the literature review were used to design interview questions and generate interview themes. As such, the expert interviews complement the literature review by adding another perspective and allowing experts to express their opinions more openly than they would in written articles, thus answering the study's research question in a cohesive manner by providing insight into the application and use of metaverse for teaching and learning, as posited in Sect. 5 (discussion of results).

3.1 Description of the search strategy for literature review

Systematic Literature Network Analysis (SLNA) was employed for article selection and analysis to ensure rigorous and unbiased analysis. To gather relevant and reliable information, various reputable databases, including Scopus, IEEE Xplore, and Web of Science, with the search terms "metaverse" OR "virtual reality" OR "education"

OR "teaching" OR "learning" limited to articles in English published within the past 20 years. Inclusion criteria for studies included peer-reviewed journal publication, addressing the use of Metaverse for teaching and learning, comparing the use of Metaverse to a traditional teaching method, and reporting at least one outcome measure related to teaching and learning. Exclusion criteria included non-English language publications, conference abstracts, and duplicate publications. Two reviewers independently screened titles and abstracts for the selected studies. Full-text articles were reviewed using a standardized form to extract data, including study design, outcome measures, and main findings. The steps of the article selection and screening process are outlined in Fig. 2. Our research team used a predetermined protocol to ensure comparable data extraction while conducting a qualitative analysis of 44 related articles. The team identified similarities and differences in functions across

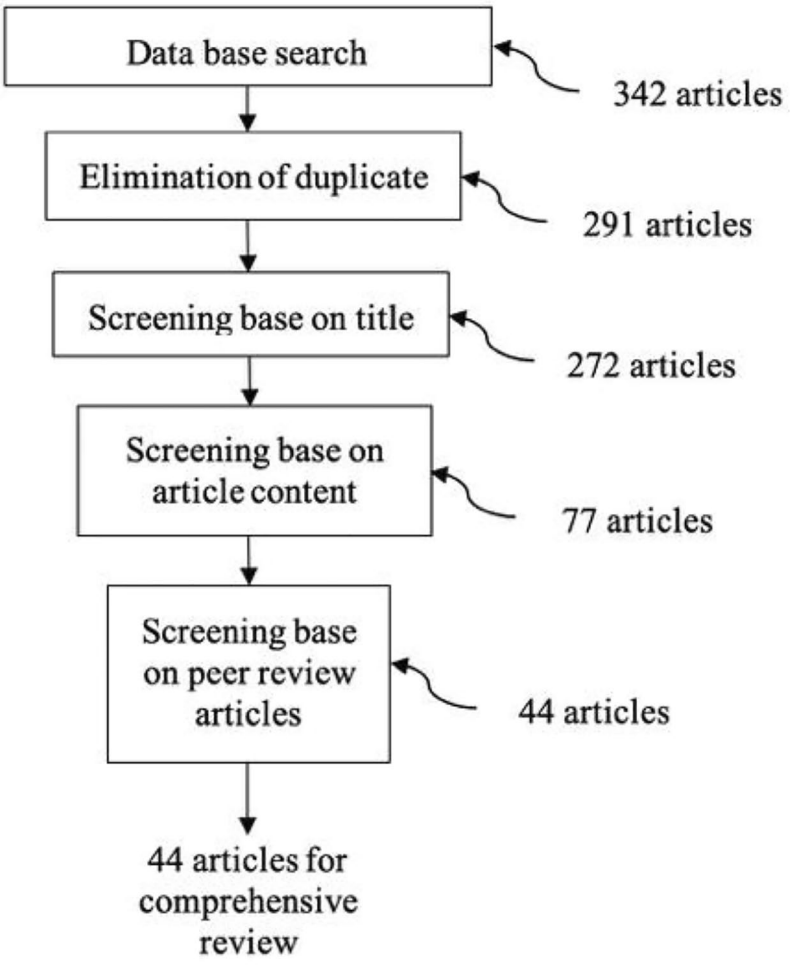

Fig. 2 Outline of article selection and screening process

databases and agreed on the potential of metaverse functions for aiding educational development.

3.2 The Cross-case in-dept interview process

The study employed in-depth, open-ended interviews to investigate the experiences and perceptions of students, educators, managers, and program administrators involved in a metaverse-based teaching and learning program. We identified key conferences on the topic in North America and Asia and located potential experts through attendance and registration. We then approached potential participants with tangible experience with immersive education, allowing us to discuss our research topic without direct access to their school or organization (case). As a result, we secured 28 interviewees with relevant expertise in Metaverse, including experience with VR, AR, MR, 3D gaming, and holographic technology. We employed diverse data sources, including semi structured in-depth interviews protocols, to collect participant data (Creswell, 2013). The researcher used open-ended questions to elicit information about the participants' experiences and perceptions of using metaverse technology in education. The researcher also asked participants about their preferences for using metaverse technology instead of traditional teaching methods and any difficulties they encountered or expected when using it in an educational context. Furthermore, we analyzed written materials such as reports or documents related to the study.

Throughout the case study interview process, we followed the protocol established in previous research (Farooq & De Villiers, 2017; Iacono et al., 2016) and used listening techniques and improvisation (iterative process) to address follow-up questions and cover a range of perspectives on the topic. Despite the small sample size, our findings are credible and valid because of the rigorous expert selection process and the semi structured in-depth interviews protocols employed with sample sizes within this range (Galvin, 2015; Gentles et al., 2015). In March 2022 and February 2023, the interviews were conducted face-to-face or via Zoom with software development, learners, and education professionals. Participants included individuals with various roles, such as "senior technology consultants," "heads of sales and business development," and "directors," as well as "professors of artificial intelligence" and "undergraduate and graduate students" who attended related conferences. The study utilized an in-depth interview method using a questionnaire structured according to (Stuart et al., 2002). Participants were requested to supply primary demographic data and then answer nine open-ended questions to investigate their comprehension of Metaverse, utilization of VR, AR, MR, and 3D gaming technologies in education, and possible factors for success in transitioning to future education.

The case study data were analyzed using a thematic analysis approach, which involved identifying patterns and themes and coding and organizing the data according to these themes, as detailed in (Braun & Clarke, 2006). Their identities have been concealed to protect the experts' and students' confidentiality. Therefore, this study's four selected "companies" represent the larger group of candidates who participated in the semi structured in-depth interview process. The characteristics of the cross-case study and participants are summarized in Table 2. After conducting a

Table 2 Cross-case study and interviewee characteristics

	Description	Participants ID	Participants Background
CASE A	As a multinational technology corporation Northwest region of the United States, the company is recognized as one of the world's most successful technology companies, with diverse products and services catering to individuals and businesses globally. Its focus areas include cloud computing, artificial intelligence, and mixed reality.	A1	Head of a department
		A2	Sales representative
		A3	Software developer
		A4	Technical Assistant
		A5	Lead Tech
CASE B	Since its establishment, this university has become one of the largest and most diverse universities in South Africa, with a student population of over 50,000 and a wide range of undergraduate and graduate programs. It's also one of the leading research institutions in the country, with a strong focus on areas such as science, technology, engineering, and mathematics (STEM). It is committed to using digital technologies to improve education and research quality and increase access to these services for its students and faculty.	B1	Professor of AI
		B2	Ph.D. students
		B3	Ph.D. students
		B4	Undergraduates
		B5	Undergraduates
		B6	Undergraduates
		B7	Associate director
CASE C	Pioneers in sustainability and circular economy, this company provides safety and performance testing, certification, and advisory services to various industries, including consumer products and electrical and electronic equipment. The company has a global presence, with offices and labs in several countries worldwide, including the United States, Canada, Europe, and Asia.	C1	Senior manager
		C2	Head of VR station
		C3	Software developer
		C4	Project manager
CASE D	Renowned for its research, teaching, and innovation excellence, this university is a leader in virtual education and its Metaverse. It boasts one of the most prominent universities in the world. It has consistently ranked in the top 10 universities in the UK. It is the largest single-site university in the UK as part of its commitment to innovation and collaboration. In this virtual world, students and staff can connect, attend lectures, and participate in various interactive activities.	D1	Professor of AI
		D2	Professor of AI
		D3	Ph.D. student
		D4	Undergraduate
		D5	Undergraduate

case study assessment to identify potential candidates, 28 individuals were selected for participation in the study. These individuals were chosen based on their relevant experience with Metaverse. Of the 28 candidates, 21 had the desired experience and attitude towards Metaverse, while the remaining 7 were either unsure of its concept or unaware of its capabilities for educational purposes, or were not in favor of its use in teaching and learning due to their specific challenges. The study solely relied on data gathered from the feedback of the 21 participants whose experience and opinion on Metaverse was suitable for the desired study objectives. The feedback provided by these participants played a crucial role in assessing the effectiveness of Metaverse in enhancing teaching and learning results and bolstering engagement. Overall, the study narrowed down the participants to a small number of individuals whose responses were deemed relevant and valuable to the research objective. The transcriptions and codes of each interview were sent back to participants for validation and clarification. Consequently, to ensure construct validity, the collected data was

triangulated with secondary sources, including the company or institutional website and other official documents available to the public (Voss et al., 2002). The datasets generated during and/or analysed during the current study are not publicly available yet because they have broad applications and are currently being prepared for publication but are available from the corresponding author upon reasonable request.

4 Results

In this section, we assess the successful implementation of metaverse technologies and analyze their potential use in education through a literature review and cross-case study supplemented with the semi structured in-depth interviews conducted among experts. In the qualitative research design, the literature review was used to gather information on the current state of knowledge on the potential of Metaverse in education. It identifies gaps in the literature and provides context for the research. The interview is instrumental in examining the strategies, decisions, and results of applied or adapted experiences to determine how to best approach the current situation and the development of the Metaverse in education. This cross-case study further helps us understand how Metaverse can be applied and adapted for teaching and learning. By leveraging the existing literature, interviewing key stakeholders, and cross-referencing across different educational contexts, this qualitative research design enables researchers to better understand the potential and consequences of using Metaverse for educational purposes.

4.1 Overview of the findings from the literature review

The literature review aimed to investigate the current state of research on using Metaverse for teaching and learning. The literature was analyzed in terms of research type, and it was found that most publications were explanatory, interpretive, and confirmatory. In addition, two main theories emerged to explain decisions related to Metaverse: immersive learning and experiential learning. Other concepts that were identified were effective learning and data privacy. As there was no comprehensive review of the research, the literature review aimed to explore and synthesize existing literature on Metaverse for teaching and learning. The potential to use Metaverse for future teaching and learning explores the current research on using metaverse technology in education. This study examines the advantages and difficulties of employing metaverse technology in instruction and learning and provides examples of successful integration of metaverse technology in educational contexts. The number of articles published per the application of Metaverse in the educational sector for teaching and learning is presented in Fig. 3. An increasing trend can be seen in Fig. 2, especially from 2019. The articles published in 2015, 2019, and 2023 are 9, 13, and 28, respectively.

This shows an exponential growth in interest in using Metaverse in the educational sector for teaching and learning, likely due to its flexibility and immersive qualities compared to traditional learning methods. This growing interest in metaverse technology reflects the ever-changing needs of students, who require more efficient and

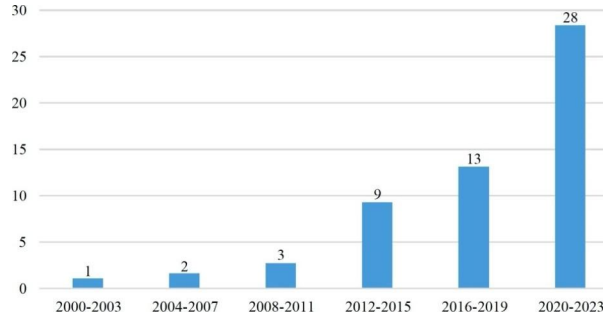

Fig. 3 Distribution of articles by the year of publication

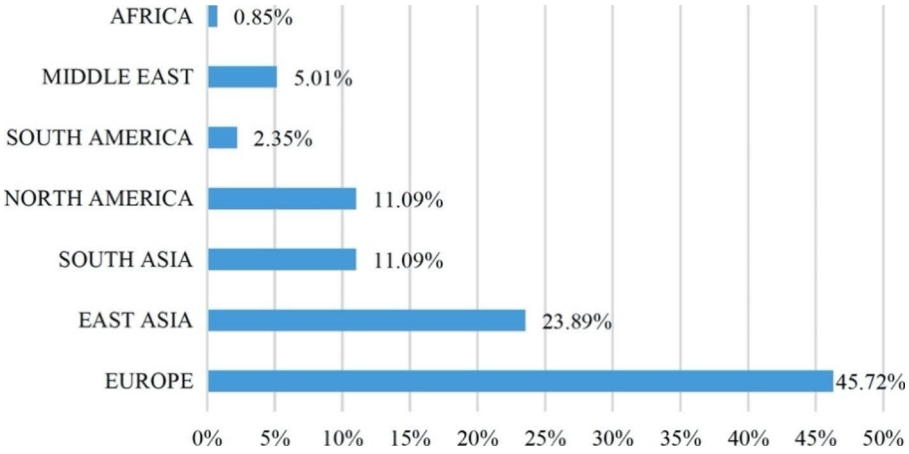

Fig. 4 Distribution of Articles by Region

engaging learning experiences to keep up with the pace of innovation in this digital age. This growth indicates a promising future for metaverse technology as more and more educational institutions adopt it to meet their students' needs and compete with the advances of other learning methods.

The distribution of articles by region in metaverse-enabled education value is shown in Fig. 4. As expected, a large number of articles (45.72%) emerged in Europe and Asia (34.98%), followed by North America (11.09%). While Europe and Asia account for the majority of articles in the field, there are still notable contributions from other regions, such as North America, South America, and the Middle East. As a result, the development of Metaverse and its associated techniques is an international priority for many universities and research institutes, with widespread recognition of the potential benefits it can bring to society. This global adoption trend of metaverse-enabled education is promising for countries beginning to explore this new technology. It also highlights the need for collaboration between countries and regions to share knowledge and resources.

4.2 Overview of the findings from the semi structured interview process

The insights gathered from the semi structured in-depth interviews yielded valuable information. Participants exhibited significant interest and enthusiasm for incorporating metaverse into education. They emphasized how its immersive and interactive nature could greatly engage students and enhance their learning experiences. Moreover, participants acknowledged the metaverse's potential for personalized and adaptive learning. They highlighted its ability to offer individualized learning paths, accommodating diverse learning styles and allowing students to learn at their own pace. This aspect was viewed as highly advantageous. However, the interviews also shed light on the challenges and limitations associated with implementing metaverse-based teaching and learning. Concerns were raised about technical infrastructure requirements, accessibility issues, and potential distractions within the metaverse environment. Addressing these challenges is crucial to ensure effective and equitable utilization of metaverse in education.

5 Discussion

5.1 Implications of metaverse to teaching and learning from literature

The literature review on using Metaverse for teaching and learning found that most publications were explanatory, interpretive, and confirmatory. Emerging scientific studies have shed light on the remarkable potential of integrating Metaverse into the realm of education (Akour et al., 2022; Díaz et al., 2020; Park & Kim, 2022a). By harnessing this transformative technology, educators can unlock a multitude of benefits (Ulaş, 2015). One such advantage is the ability to offer students immersive and interactive learning experiences that go beyond traditional classroom boundaries. Through Metaverse, learners can delve into captivating virtual environments and actively engage with the subject matter, fostering deeper understanding and knowledge retention (George Reyes, 2020; Hanid et al., 2020). Moreover, Metaverse has the capacity to facilitate personalized and adaptive learning. By tailoring educational content and experiences to individual students' needs and preferences, educators can create a more tailored and effective learning journey (Frost et al., 2020; Kounlaxay & Kim, 2020). This customization enables learners to progress at their own pace, enhancing their comprehension and overall educational outcomes. Another notable advantage of Metaverse in education lies in its potential to foster international collaboration and knowledge sharing (Pricer, 2010). Regardless of geographical location, students from around the world can connect and collaborate within virtual spaces, transcending physical boundaries. This globalized learning environment promotes cultural exchange, diversity, and a rich exchange of ideas, resulting in a broader perspective and enhanced learning outcomes.

However, to fully harness these advantages, it is imperative to establish appropriate safety protocols within Metaverse (M. Díaz et al., 2016). Educators and technology providers must work collaboratively to ensure a secure and trustworthy virtual environment for all participants. This includes safeguarding student data and privacy,

implementing measures to prevent cyber threats, and promoting responsible online behavior. Furthermore, equitable access to digital resources is crucial to ensure that all students, regardless of their socio-economic status, can benefit from the educational opportunities offered by Metaverse (S. M. Park and Kim, 2022b). Efforts should be made to bridge the digital divide, providing necessary infrastructure and resources to underserved communities. This inclusivity will promote equal opportunities and empower learners from all backgrounds to thrive in the digital age. Additionally, effective assessment strategies and measures to evaluate student performance within Metaverse are essential. Educators need to develop innovative and meaningful ways to gauge learning outcomes and progress within virtual environments (Hanid et al., 2020). This may involve leveraging immersive assessments, virtual simulations, and data analytics to gain insights into students' achievements and identify areas for improvement. By embracing the potential of Metaverse, education can transcend physical limitations and reach a wider audience. This transformative technology has the power to engage learners from all corners of the globe, making education accessible to individuals who may otherwise face geographical, economic, or social barriers. Embracing Metaverse opens doors to boundless educational opportunities and paves the way for a more inclusive and interconnected future of learning.

Two main theories have emerged to explain decisions related to Metaverse: immersive education and experiential learning. The other identified concepts were practical learning and data privacy. The number of articles published on using Metaverse in the educational sector for teaching and learning has been increasing, especially since 2019—Europe and Asia combined account for the majority of articles in the field, followed by North America. The study's results suggest that using Metaverse for teaching and learning can lead to improved learning outcomes and increased engagement. These findings are consistent with previous research on using VR in education, showing that immersive and interactive learning environments can enhance learning and motivation (Sumit Patel et al., 2020). There are several possible explanations for these positive effects:

1) Metaverse allows for a fully immersive and interactive learning experience, enhancing the sense of presence and making the learning experience more engaging and realistic (Pricer, 2010).
2) Metaverse allows the creation of customized and personalized learning environments that can be tailored to the needs and interests of individual learners (Dominguez-Noriega et al., 2011).
3) Metaverse allows for the creation of collaborative and social learning experiences that can foster teamwork and communication skills (Jovanović & Milosavljević, 2022).

Based on current scientific research, the efficacy of Metaverse in the realm of teaching and learning remains uncertain. There is limited evidence available, suggesting that the use of Metaverse may not be universally suitable for all subjects, learners, or regions. Factors such as economic conditions and technological advancements play a significant role in determining the feasibility and effectiveness of incorporating Metaverse into education. Furthermore, the existing research on the impact

of Metaverse on education has identified several gaps that need to be addressed. These gaps include the exploration of ways to enhance metaverse-based teaching and learning programs, an in-depth analysis of the advantages and challenges associated with learning in the Metaverse, and an understanding of how the Metaverse can complement traditional teaching methods. Additionally, research is needed to ensure inclusive and equitable use of Metaverse among students, examine how the roles of teachers and students may evolve in a Metaverse-based classroom, and address privacy and security implications when utilizing Metaverse for educational purposes. Furthermore, it is important to gather more case studies on the practical applications of metaverse-based teaching approaches. To bridge these research gaps, a series of semi structured in-depth interviews was designed. These interviews aimed to gain deeper insights into the conditions under which Metaverse proved the most effective for teaching and learning. The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request. By exploring these areas of inquiry, educators and researchers can gain a comprehensive understanding of the potential of the Metaverse in education and develop strategies to maximize its benefits while addressing any limitations or concerns that may arise.

5.2 Insights and lessons learned from the In-depth interview on using Metaverse for Teaching and Learning

1) Exploring the Educational Benefits of the Metaverse: One of the key lessons from the in-depth interviews concerns the educational benefits of the Metaverse. Interviewees were asked the first question of the survey to provide a specific example of how the Metaverse has helped you educate or learn in a way that traditional methods have not. Accordingly, participants-C3 reported: …*Metaverse can provide a sense of immersion and interaction not possible in traditional classroom settings and allowed for more engaging and authentic learning experiences.* A unanimous report supported the effectiveness of metaverse-based teaching and learning programs, in which students exposed to virtual and augmented reality technologies exhibited higher engagement and satisfaction with the program. Furthermore, participants-D4 reported that …*Metaverse is seen to support personalized and adaptive learning, allowing students to learn at their own pace and engage in more meaningful and relevant learning experiences.*
2) Strategies for Enhancing Metaverse-based Teaching and Learning: The second question asked what suggestions do you have to improve the metaverse-based teaching and learning program? Participants A3, C3, and A4 proposed that, to maximize the benefits of educational metaverses, educators must develop and implement appropriate safety protocols, prioritize equitable access to digital resources, incorporate meaningful assessment strategies, and find ways to assess student performance effectively. Comment by participant B7: *Educators must work to build an environment of trust and collaboration within Metaverse so that students feel comfortable exploring and expressing their ideas without fear of judgment or retribution.* As such, combined with intentional and creative teaching approaches, these elements will allow students to experience a unique

learning environment, leading to increased collaboration, creativity, and academic achievement.

3) Exploring the Pros and Cons of Learning in the Metaverse: "Navigating the Metaverse of Learning" refers to navigating and understanding the virtual world of learning, which includes online and virtual educational experiences. The respondents posited the benefits of utilizing Metaverse for education based on the following question: What are the main advantages and challenges of learning in Metaverse? The recurrent themes of accessibility and flexibility, and any associated challenges, such as the lack of face-to-face interaction or the potential for distractions, were discussed. The participants identified the potential for international collaboration and knowledge sharing to help countries explore this new technology and ensure that everyone can access innovative educational experiences (C2, A1). In their responses, the respondents (B3, B6, and D2) noted that utilizing Metaverse would allow for a larger audience, allowing people to learn regardless of their physical location or socioeconomic status.
4) Enhancing Teaching and Learning Through the Use of the Metaverse: Metaverse has facilitated virtual field trips, simulations, and other hands-on activities that can supplement the traditional classroom instruction. This study aims to understand how the capabilities of Metaverse can lead to excellence in teaching and learning and poses the following questions to the participants: How do you see the Metaverse being used to enhance or supplement traditional teaching and learning methods? Comment B1: *The Metaverse can provide a platform for teachers to connect, collaborate, share best practices, and attend virtual workshops and training sessions.* This can help support teachers' ongoing professional development and enhance their ability to effectively educate students. *Metaverse technology can be used to support remote learning and distance education. With the increasing prevalence of online and distance education, Metaverse can provide a way for students to interact with each other and their teachers in a virtual environment, which can help mitigate the isolation and lack of engagement that can occur in a purely online learning environment* (the information comes from Participant D3).
5) Overcoming the Limitations of Metaverse-Based Teaching and Learning: Respondent comments to "What are the current limitations of metaverse-based teaching and learning programs, and how can they be overcome?" The key limitations that may hinder the widespread adoption of metaverse-based teaching and learning programs are summarized as follows:

    i. Technical limitations: The technology required to create and access metaverse environments remains early, expensive, and challenging.
    ii. Hardware and software requirements: Accessing and interacting with Metaverse can be prohibitive for some users.
    iii. Limited content: Currently, little educational content is available in Metaverse, making it difficult for educators to find and use relevant class materials.
    iv. Lack of standardization: Metaverse is a relatively new concept, and there is currently no standardization in terms of platforms, tools, and protocols used

to create and access virtual worlds. This can make it difficult for educators and students to navigate and utilize different metaverse environments.

v. Privacy and security concerns: As with any online environment, there are concerns about privacy and security in Metaverse. This can make it difficult for educators and students to feel comfortable sharing their personal information and engaging in online activities.

To overcome these limitations, Participant A2 proposed that there needs to be more investment in developing metaverse technology and creating more educational content and tools specifically designed for use in Metaverse. According to Participant C4, *efforts should be made to standardize the platforms, tools, and protocols used in Metaverse and to address privacy and security concerns by developing secure and private metaverse environments.* Furthermore, Participant B1commented that: *research and development in the metaverse-based teaching and learning field is needed to understand how to best use this technology to enhance teaching and learning.*

6) Promoting Equity and Inclusion in Metaverse-based Teaching and Learning: Several key strategies ensure that Metaverse is used inclusively and equitably for all students. We asked respondents to respond to the "How to ensure that the metaverse is being used inclusively and equitably for all students?" All students should be afforded the necessary equipment and Internet access to participate in metaverse-based learning, training, and support to help them navigate the technology. (Participant D4). Virtual content and activities must be culturally responsive and reflect the diversity of the student population (Participant B3). Ensuring the equitable and inclusive use of metaverse technology requires providing students with opportunities to give feedback and input, co-create and co-facilitate virtual learning experiences, and continually evaluate the effects of metaverse-based learning on student outcomes (the information also comes from the professor of AI in Case B).
7) Exploring the Evolving Role of Teachers and Students in the Metaverse: Metaverse technology can significantly change the roles of teachers and students in the classroom. One fundamental way to do so is to provide new opportunities for student-centered, collaborative learning experiences. Participants were asked; How do you think the Metaverse will change the roles of teachers and students in the classroom? There was a unanimous contribution in that teachers may serve more as facilitators and guides than traditional lecturers to help students navigate the virtual environment and provide guidance on using the various tools and resources available. The virtual reality aspect of Metaverse can allow students to have a first-hand experience of things that would have been impossible or impractical in the physical world. Comment by Participant D3: using avatars in Metaverse will allow for greater anonymity and social freedom, which can be especially beneficial for students who may feel shy or marginalized in traditional classroom settings.
8) Assessing the Privacy and Security Implications of Teaching and Learning in the Metaverse: As with any new technology, there are concerns about the privacy and security of students and educators when using metaverse for teaching

and learning. What are the implications for the privacy and security of students and educators when using Metaverse for teaching and learning? The technical lead from CASE A agrees that data breaches and unauthorized access to personal information by hackers or other malicious actors raises significant security concerns. Comments by Participant D1: As students and educators interact in a virtual environment, they may be exposed to cyberbullying, harassment, or other online abuses. As such, because metaverse is not always moderated, individuals may have opportunities to engage in illegal activities or inappropriate access to content.

9) Exploring Metaverse-Based Teaching and Learning in Specific Subject Areas: The last question in the in-depth interview asked the participants to discuss any current or future use cases of metaverse-based teaching and learning in specific subject areas. Second Life, as a metaverse platform, was the most popular, as discussed by all respondents. Given its application as a metaverse platform, the difference participants cite examples based on their knowledge of the application of Second Life. The Massachusetts Institute of Technology (MIT) conducted virtual classes, workshops, and lab sessions; the University of Missouri created a virtual campus for students to interact, attend classes and events, and collaborate; and the Universities of Manchester and Edinburgh hosted virtual open days, virtual tours, and other events for prospective students. San Jose State University, to create virtual field trips, allowing students to explore historic sites and other locations around the world without leaving the classroom; Purdue University and Texas A&M University, to create virtual lab simulations for students in engineering, architecture, and science courses; and the University of California, Los Angeles, to use it in their medical school curriculum to simulate surgeries and other medical procedures.

6 Discussions

6.1 Implications of the findings for the use of the metaverse for teaching and learning

One of the key advantages of Metaverse in teaching and learning is its ability to create immersive and interactive learning environments. Metaverse allows educators to design and deliver virtual experiences that authentically engage learners and provide a sense of presence and social presence that is impossible in traditional classroom settings. For example, Metaverse has been applied to create virtual simulations and virtual field trips, which have helped students learn complex concepts and real-world situations more engagingly and interactively. Another advantage of Metaverse for teaching and learning is its potential to support personalized and adaptive learning. Metaverse can provide tailored learning experiences based on individual learner needs, preferences, and learning styles and can adapt to learners' progress and feedback in real-time. This can help students learn independently and engage in meaningful and relevant learning experiences. Literature suggests that Metaverse has the potential to be a powerful and innovative platform for teaching and learning (Chen

& Zhang, 2022; Kye et al., 2021; Lee & Kim, 2021; Son et al., 2022). However, the use of metaverse for teaching and learning has several challenges and limitations. One of the main challenges is the lack of standardization and interoperability among different metaverse platforms, making it difficult for educators to develop and deliver consistent and practical learning experiences.

Despite the potential of Metaverse for teaching and learning, there is still a lack of research and evidence to support its effectiveness. Determining the best practices and guidelines for its use in education is difficult. However, by collecting feedback from participants, monitoring usage and engagement data, evaluating learning outcomes, and tracking progress over time, we can start to build evidence and identify practical approaches for metaverse-based teaching and learning programs. With such evidence, educators can make informed decisions using Metaverse to maximize their learning potential and develop innovative teaching methods. Going forward, educational institutions must create frameworks to ensure responsible and ethical use of the Metaverse and implement mechanisms that protect the safety, privacy, and well-being of students, staff, and other stakeholders involved in metaverse-based learning environments. The in-depth interview results showed that the metaverse-based teaching and learning program was perceived positively by students, educators, and program administrators as an innovative and effective way to deliver education. In the study, respondents identified several barriers that need to be addressed to ensure the success of Metaverse in education, such as:

1) The expenses associated with building and maintaining a network and providing digital infrastructure and connectivity: Building and maintaining a network and providing digital infrastructure and connectivity to deploy a metaverse require hardware, software, and personnel expenses. Accordingly, Participant C1: Hardware costs include purchasing and installing routers, switches, servers, and other networking equipment. Software costs include licensing software applications and security solutions to secure the network. Personnel costs include hiring a cross-case in-depth interview and training skilled network administrators, engineers, and technicians to manage the network and monitor its performance. Lease fees for lines, bandwidth, and storage space may also be included in providing digital infrastructure and connectivity costs. Finally, costs associated with deploying a metaverse may consist of fees for hosting services and software licenses.
2) The adoption of standardization and certification is needed to implement metaverse technology in the educational sector: This would involve having a unified set of rules and regulations that schools, teachers, and other educational institutions must adhere to ensure the technology is used safely and effectively. Comment by Participant C4: Without proper standards and certifications, implementing metaverse technology in the educational sector would be difficult, if not impossible.
3) Reliability, data privacy, and security requirements for using Metaverse in teaching and learning: The metaverse must prioritize reliability and consistency to ensure that the platform is always available and operational, avoiding unexpected downtimes or system failures. (Participant B2). Additionally, the protection of

user data must be a top priority, with robust security measures in place to prevent unauthorized access, use, or disclosure of user information. Users should also have control over their data, including limiting access and deleting any data they no longer wish to keep. According to participant B7: To make the most out of the Metaverse in education, researchers and educators must engage in rigorous data collection and analysis to build an evidence base to inform educational policies, practices, and implementation strategies. Furthermore, Metaverse must have robust security protocols, including user authentication and encryption, to protect its users from potential cyber threats.

4) Organizational Culture and Barriers to Institutional Readiness for Utilizing the Metaverse for Teaching and Learning: The organizational culture and institutional readiness are critical factors that can affect the successful implementation and adoption of Metaverse for teaching and learning. A positive corporate culture that values innovation and technology can support the performance of Metaverse, whereas a negative culture may be a barrier to its adoption according to participant-B7. Additionally, Participant-D2, posit on institutional readiness for the metaverse implementation may include assessing the availability of resources such as technology infrastructure, human resources, and funding. According to the participant, the scenario calls for evaluating the willingness of organizations to invest in the necessary resources, training, and change management processes. It may require assessing the readiness of the organization to adapt to new ways of teaching and learning, including the use of virtual reality and the ability to adjust technology to the specific needs of learners and educators. In essence, Participants B7 and D2 posit that assessing and addressing organizational culture and institutional readiness are critical factors to ensure the successful implementation and adoption of metaverse for teaching and learning.
5) Specialized skills are needed to create and employ Metaverse technology in educational settings: Specialized expertise is required to design, develop, and utilize Metaverse in education (Participant A1), as it encompasses various technical skills in virtual reality, artificial intelligence, and programming and pedagogical skills to design practical educational experiences. In addition, it may include skills in data privacy, cybersecurity, and accessibility to ensure that Metaverse is inclusive and equitable for all learners. Furthermore, it requires an understanding of the educational context and the ability to adapt technology to the specific needs of learners and educators. Therefore, the need for specialized skills to develop and use Metaverse in education is crucial to ensure that technology is used effectively and ethically.

6.2 Unique contribution of the research

This study presents an in-depth examination of the potential use of Metaverse in future education through a literature review and in-depth interviews. To the best of our knowledge, this research is among the first to explore the topic of metaverse-based teaching and learning in such a comprehensive manner. The findings of this study confirm and expand upon previous research, highlighting the immersive and interactive capabilities of Metaverse, according to our subject experts, and its poten-

tial to support personalized and adaptive learning. Several key themes are critical to the successful development and deployment of Metaverse. These include awareness, user and facilitator education, safety, responsibility, relevant legislation, and reliability. Addressing these priority areas is crucial for ensuring a smooth transition to an education-centric paradigm, and must be considered before the full-scale launch of the Metaverse. However, the study also identifies challenges and limitations that must be addressed to effectively utilize Metaverse for teaching and learning, emphasizing the need for continued research and development in this field. This information is vital for educators and policymakers to consider when evaluating the use of Metaverse in education.

6.3 Limitations and future research direction

In metaverse training, it is evident that many elements and factors must undergo significant changes, and new fields of expertise will be required. Therefore, it is crucial to understand the concepts of understanding, narration, and application, which are the initial stages of the Metaverse and educational transformation. This understanding should be grounded in a pedagogical approach that considers the unique aspects of the Metaverse environment. For instance, the Design for the Metaverse should consider the immersive and interactive nature of Metaverse environments. In contrast, Metaverse Pedagogy should consider how to design customized learning paths for each student based on their individual needs and learning styles.

Furthermore, Avatars are an essential part of metaverse environments, and Design for Avatars should focus on creating avatars that can represent users' identities and facilitate engagement with the learning materials. Applications for Metaverse Artificial Intelligence should also be explored using artificial intelligence to enhance learning and facilitate interactions between users and learning materials. Finally, Sociology in Metaverse should be considered to understand how social interactions can impact learning outcomes and how to design metaverse environments that foster positive interactions among learners. Overall, a transformational education system where the potential of Metaverse can be realized. This system should include technical infrastructure, educational content providers, and pedagogical approaches that consider the unique aspects of metaverse environment. For Metaverse to effectively utilize its available resources and effectively function in educational contexts, international and national cooperation must be established. To successfully develop the required technology, software, content, and human resources, academic and non-academic entities must work together in a coordinated and well-thought-out manner.

7 Conclusions

In conclusion, Metaverse, a virtual reality space that allows for fully immersive and interactive experiences, has the potential to revolutionize the way we teach and learn. This systematic literature review suggests that using Metaverse for teaching and learning can lead to improved learning outcomes and increased engagement. Based on the analysis of the cross-case study interview design, there is no doubt that

this technology will play a significant role in the future of education. As the world becomes more digital, adapting to new technologies and learning new skills is crucial for success in the 21st century. The Metaverse represents the next evolution of virtual reality in education. The use of Metaverse for teaching and learning may not be suitable for all subjects and learners, and more research is needed to understand the conditions under which Metaverse is most effective. In essence, future research should explore the effectiveness of the Metaverse in supporting personalized and adaptive learning that allows students to learn at their own pace and engage in more meaningful and relevant learning experiences, including standardization and interoperability issues.

In summary, the literature review and in-depth interview analysis indicate that Metaverse has the potential to be a transformative platform for teaching and learning but also highlights the challenges and limitations associated with its use in education. This article stresses the need to tackle issues such as network and connectivity requirements, reliability, standardization and certification, organizational culture and readiness, and specialized skills to fully leverage Metaverse's potential in education. Furthermore, it highlights the importance of continued research and evidence gathering to fully understand Metaverse's effectiveness in teaching and learning.

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Declarations

Competing interests The authors declare no competing interests.

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