Metaverse applications in education: A systematic review and a cost-benefit analysis

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Abstract

Purpose: Many educators are increasingly acquainting themselves and becoming adept with interactive technologies like augmented reality (AR) and virtual reality (VR). Some of them are also looking forward to utilizing Metaverse applications, as they want to benefit from its immersive three-dimensional (3D) capabilities. Therefore, this research critically reviews the extant literature to investigate how, why, where and when the Metaverse can be used for educational purposes. It also discusses about opportunities, challenges and risks related to this disruptive technology.

Methodology: A Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) rigorous protocol is used to search, extract, scrutinize and synthesize content from high-impact articles focused on the use of the Metaverse technology in the realms of education. Afterwards, this research theorizes on the costs and benefits of using this interactive technology with students.

Findings: A number of researchers are already experimenting with virtual technologies that are very similar to the Metaverse, in different contexts. This research indicates that most students are lured by immersive multi-sensory 3D environments as well as by VR applications that could simulate real life situations and provide engaging experiences with virtual representations of people, places and objects. On the other hand, it reveals that educators ought to consider the potential pitfalls of the Metaverse, including privacy breaches and security risks, as well as possible addictions and the development of mental health issues, among others.

Practical implications: Students and educators can use the Metaverse to catapult themselves in a simulated digital universe that could reconfigure their sensory inputs, definitions of space, time and points of access to information. This research calls for the development of regulatory instruments including of sound principles, guidelines and procedures that are intended to safeguard and protect Metaverse users.

Originality: This contribution implies that there is scope for educators to continue developing the Metaverse's virtual spaces in order to improve their students' motivations, aptitudes and learning outcomes. It clarifies that the use of the Metaverse in education can create infinite possibilities to enhance their knowledge, competences and abilities through its immersive applications. Yet, it also raises awareness on possible challenges in the short term as well on other risks associated to the prolonged use of this captivating technology.

Keywords: Metaverse, education, learning, immersive technologies, augmented reality, virtual reality.

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1. Introduction

Online users are increasingly connecting to simulated virtual environments through various digital games (Barry *et al.*, 2015) like Fortnite, Minecraft, Roblox, and World of Warcraft, among others. For instance, as of the first quarter of 2022, gaming company Roblox had over 54.1 million daily active users (Statista, 2022). Most of them are under the age of 16 (McKinsey, 2022). Very often, they are utilizing VR and AR technologies to improve their gaming experiences (Almarzouqi *et al.,* 2022; Kye *et al.,* 2021; Jovanović and Milosavljević, 2022). New users to such games are expected to create electronic personas, called avatars (that represent their identity in the virtual world) (Chen *et al.*, 2020; Díaz, 2020; Garrido-Iñigo and Rodríguez-Moreno, 2015; Park, and Kim, 2022). They are allowed to move their avatars around virtual spaces and to use them to engage with other users, when they are online. In many cases, they are engaging with other individuals in the cyberspace and participating in an extensive virtual economy (Cortés Rodríguez *et al.*, 2022; de Silva, 2021; Lee & Hwang, 2022; Lee *et al.,* 2022a; Lee *et al.,* 2022b; Makranski and Mayer, 2022). Such interactive games are enhancing their users' immersive experiences, particularly those that utilize VR headsets to catapult themselves in virtual environments.

A number of academic researchers as well as practitioners representing technology giants like Facebook (Meta), Google and Microsoft, among others, are working on a multitude of virtual universes they called the Metaverse (Dwivedi *et al.,* 2022; Hwang and Chien, 2022; Jovanović and Milosavljević, 2022; Kye *et al.,* 2022; Park *et al.,* 2021; Zhou *et al*., 2022a). In short, they anticipate that this disruptive technology could change the way how we experience the Internet (Akour et al., 2022; Yue, 2022). Some commentators argue the Metaverse has become an over-hyped term, and it's important to note that it is still in the research and development phase at the moment.

For the time being, there is no universal definition that encapsulates the word "Metaverse". The term has been used in a 1992 science fiction novel Snow Crash. Basically, it is a blend of two words,

namely "meta" and "universe". While meta means beyond, universe is a notion that is typically used to describe an iteration of the internet that consists of persistent, immersive 3D virtual spaces that are intended to emulate physical interactions in perceived virtual worlds (like a universe) (Chang et al., 2022; Girard and Robertson, 2020; Lee and Hwang, 2022).

Whilst on the internet, online users are interacting with other persons through websites, including in games and social media networks (SNSs) (Barhoumi *et al.*, 2022; Camilleri, 2019; Camilleri and Camilleri, 2022a; Marques *et al.,* 2021; Zhou *et al.*, 2022b), in the Metaverse they will probably engage with them through their avatars. This is what they do when they use VR technologies. They may be in a position to experience places, and things in a simulated universe (Diaz, 2020; Park, and Kim, 2022). Various commentators suggest that VR technologies will place Metaverse users in the middle of the action, in a virtual environment (Chang *et al.,* 2022; Cortés Rodríguez *et al.* 2022; Kye *et al.*, 2022; Lee and Hwang, 2022). They anticipate that this immersive technology shall reconfigure the online users' sensory inputs, definitions of space, and points of access to information (Gómez-Zará *et al.,* 2023).

AR and VR devices are already being used to improve the students' experiences when they engage with serious games. Several researchers noted that such interactive technologies encourage active learning approaches (Barry *et al.*, 2015) as well as social interactions among students and/or between students and their teachers (Estudante and Dietrich, 2020; Hadjistassou, 2016; Melendez Araya and Hidalgo Avila, 2018; Suzuki *et al*., 2020). The serious games may usually provide "gameful experiences" (Park and Kim, 2022), particularly if they offer immersive features that captivate their users' attention spans, like those relating to the entertaining games. If they do so, it is very likely that students would enjoy their game play (and game-based learning). Similarly, the Metaverse can be utilized as an educational technology to increase the students' motivations and learning outcomes.

Although, there are various academic contributions that have explored the utilization of online educational technologies, including AR and VR, in different contexts, currently, just a few researchers have prepared a thorough review of the latest literature on the Metaverse. For the time being there are still limited papers on the use of this immersive technology in the realms of education. Therefore, this contribution addresses this knowledge gap in the academic literature.

The underlying objectives of this research are threefold: (i) It relies on PRISMA's methodical protocol to search, screen, extract and synthesize content from previous research focused on "Metaverse" and "education"; (ii) It identifies and appraises those authors who published contributions (through Scopus-indexed journals) on the use of the Metaverse applications for educational purposes. It scrutinizes their work in its entirety, and evaluates their articles' research question(s), methodologies/approaches that were used to capture (and analyze) primary and/or secondary data. It also outlines their theoretical and/or practical implications; and (iii) It provides a discursive argumentation about the pros and cons of adopting Metaverse's captivating virtual technologies, in the realms of education. The underlying research questions of this bibliographic study are: *How, why, where and in what ways can the Metaverse's immersive applications be used in education? What are the costs and benefits of using the Metaverse as an educational technology?*

2. Methodology

A PRISMA's rigorous protocol is used to systematically review academic articles indexed in Scopus. This methodology is considered as a very rigorous and trustworthy approach (Liberati *et al.*, 2009). Its transparent protocol increases the legitimacy, credibility and dependability of secondary research. It enhances the confirmability of the findings, as the results from the search query can be corroborated by other researchers in different settings (if they follow the procedures that are explained in

the following section). Figure 1 provides adequate and sufficient details about the inclusion and exclusion criteria that were adopted in each stage of this systematic review.

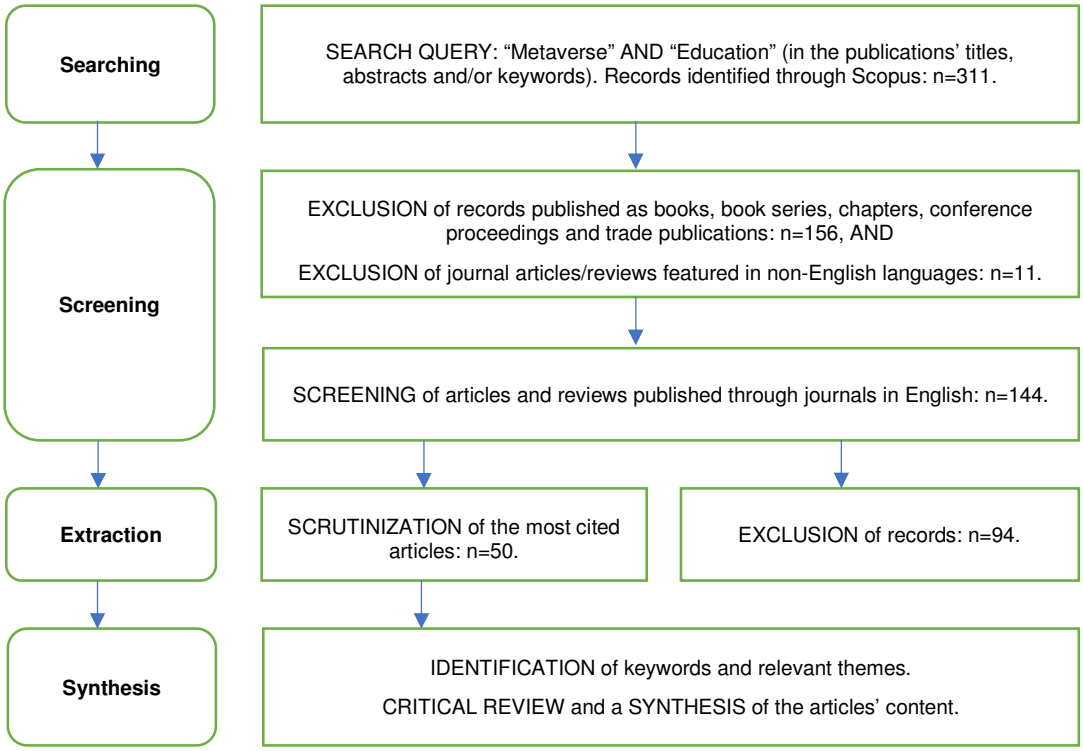

Figure 1. A PRISMA protocol for systematic analysis (developed by the author)

2.1 Searching

The keywords "Metaverse" and “education” were inserted in Scopus’ repository. The query sought whether these two items were featured in the publications’ titles, abstracts and/or keywords. Initially, the preliminary results indicated that there were three-hundred eleven (311) contributions. The results featured a complete list of contributing authors and shed light on their publications’ subject areas and keywords. The findings distinguished between different subject areas, document types, publication stages, source titles, keywords, affiliations, funding sponsors, countries, source types as well as languages. They could be sorted in chronological order (newest or oldest date), by the first author’s

surname (A-Z or Z to A), in alphabetical order (A-Z or Z to A), by relevance, by number of citations (highest to lowest or lowest to highest), and according to the source title (A-Z or Z to A).

2.2 Screening

The results indicated that there were one hundred forty-four (144) publications when the search was narrowed down to articles and reviews published through journals, in English, since 2015. Therefore, this review covered the last 100 months (between January 2015 and April 2023). The search query excluded publications that were featured in books, book series and trade publications (n=156). It also disregarded journal articles/reviews published in non-English languages (n=11). The screening phase has yielded one hundred forty-four (144) documents.

2.3 Extraction

Fifty (50) of the most cited articles and reviews that were published through Scopus-indexed journals were extracted for the purpose of this bibliographic study. They were examined, in their entirety, to ensure the accountability, integrity, and transparency of the results.

This research identifies the authors who published their contributions focused on the utilization of the Metaverse in education, it examines their research question(s) and describes the methodologies that were used to capture (and analyze) the data. Afterwards, it summarizes their implications. Table 1 presents a list of these extracted articles.

Table 1. A list articles focused on the use of the Metaverse in education (developed by the author)

Authors	Year	Source title	Research question	Methodology	Implications
Alawadhi *et al.*	2022	South Eastern European Journal of Public Health	This research investigates the factors affecting medical students' acceptance of the Metaverse in their training in the United Arab Emirates.	Quantitative	The researchers indicate that there are significant effects between the students' perceived ease of use and perceived usefulness of metaverse technologies on their personal innovativeness. These factors can affect their intentions to continue using them.
Almarzouqi *et al.*	2022	IEEE Access	This research evaluates the students' perceptions about the Metaverse's applications in medical education.	Quantitative	The researchers report that user satisfaction was found to be an essential determinant of the users' intentions to use the Metaverse.
Bansal *et al.*	2022	IEEE Access	This research examines the latest Metaverse developments in the healthcare industry.	Discursive	The researchers elaborate on the use of the Metaverse in telemedicine, clinical care, education, mental health, physical fitness, as well as in the veterinary, and pharmaceutical industry sectors. They discuss about the challenges that must be tackled before fully embracing the Metaverse in these domains.
Bühler *et al.*	2022	Education Sciences	This research discusses about novel technology-enhanced, personalized, student-centered approaches within engineering education.	Discursive	The researchers argue that AI will enable effective and personalized student learning. They argue about its positive implications on higher education service providers.
Chen	2022	Interactive Learning Environments	This research explores the Metaverse's application scenarios and evaluates how it may affect education.	Discursive	The researcher contends that the Metaverse technology can support several aspects of online classrooms, with realistic senses, personalized teaching models, realistic 3D identities, interactive communication, virtual reality (VR) technology, and gamified learning. He also identifies difficulties, interaction issues, content production, game addiction, privacy, and ethics, among others.
Cortés Rodríguez *et al.*	2022	Journal of Molecular Graphics and Modelling	The research investigates online AR software that offers interactive content for chemistry and structural biology education.	Experimental	The researchers present new tools to help users create their own web-based AR or VR views from plain PDB files. They posit that they can be used by educators and science communicators (they are open for free use without registration).

Dahan *et al.*	2022	Electronics (Switzerland)	This research examines some previous works to find out special technologies that should be provided by the Metaverse framework. It discusses about the use of the Metaverse in an E-Learning environment.	Discursive	The researchers put forward a framework that is intended to improve the virtual learning environment.
Díaz *et al.*	2020	International Journal of Emerging Technologies in Learning	This research describes the integration of the Metaverse with hybrid and mobile learning models.	Experimental	The researchers develop a virtual world as a digital tool to support students and teachers.
Díaz	2020	International Journal of Emerging Technologies in Learning	This article addresses the issue of the design, development and implementation of a virtual or metaverse world in a university environment.	Experimental	The researchers emulate a real university institution through the Metaverse. They create a virtual world for hybrid learning.
Dwivedi *et al.*	2022	International Journal of Information Management	This research examines various Metaverse topics. It presents different narratives and perspectives from colleagues hailing from diverse backgrounds.	Discursive	Forty-two researchers share their insights on the Metaverse. They discuss about its opportunities and challenges. They also put forward research avenues to academia.
Ge	2022	Journal of Environmental and Public Health	This research discusses about multiple influences from intelligent technologies on network behaviors of college students.	Discursive	The researcher elaborates on the opportunities and challenges brought by intelligent technologies in the meta-universe era. She outlines future research directions to continue studying how intelligent technologies affect student behaviors.
Guo and Gao	2022	Frontiers in Psychology	This research explores the students' experiences during their English lessons by using an emotion electroencephalogram (EEG).	Experimental	The researchers demonstrate that the students can learn English through a Metaverse-powered system. This technology helps them to develop their sense of interactivity, immersion, and cognition abilities.
Gupta *et al.*	2022	IEEE Signal Processing Magazine	This article systematically reviews the integration of fundamental and advanced signal processing techniques focused on augmented reality (AR) or mixed reality (MR) audible experiences.	Descriptive	The researchers argue that there is an opportunity to deliver realistic, immersive audio content to users of AR. Their contribution raises awareness on signal processing techniques including on sound sensing, real sound control, and virtual sound rendering.
Huh	2022	Journal of Educational Evaluation for	This research discusses about the utilization of the Metaverse terminology for health education.	Review	The researcher commends that their review article will be helpful to better understand the concept of the Metaverse. They identify the strengths and

		Health Professions			limitations of its application for medical and health educators.
Hutson	2022	Societies	This research investigates how virtual reality and the Metaverse can be used to support introvert students and those with autism spectrum disorder (ASD).	Review	The researcher contends that the Metaverse can provide new opportunities for students with different abilities, to enhance their communication and collaboration skills.
Hwang and Chien	2022	Computers and Education: Artificial Intelligence	This research discusses about possible applications of the Metaverse in educational setting and elaborates on potential challenges.	Discursive	The researchers present their recommendations for future research on the use of Metaverse in education. They identify ten areas that require further investigation.
Hwang	2023	Computers and Education	This research explores the effectiveness of Metaverse applications for students who are aspiring to develop digital content to participate in a contest.	Sentiment analysis	The researcher suggests that the students held positive opinions about the Metaverse. He puts forward a TMIOS model (Thinkering, Making, Improving, Owning, Sharing) for Metaverse content developers.
Jovanović and Milosavljević	2022	Electronics (Switzerland)	This research introduces a novel platform that provides assistive tools to build an educational experience in virtual worlds. The authors develop a high-level software architecture and design a Metaverse platform named 'VoRtex'.	Experimental	The authors analyze the benefits and disadvantages of collaborative learning between the Metaverse platform and real-world classroom sessions.
Kye *et al.*	2021	Journal of Educational Evaluation for Health Professions	This research defines four types of the Metaverse including augmented reality, lifelogging, mirror world and virtual reality.	Review	The researchers discuss about the potential applications of the Metaverse and on its limitations when it is used for educational purposes.
Lee *et al.*	2022	Applied Sciences (Switzerland)	This research proposes a system that incorporates virtual reality (VR) and Metaverse methods into the classroom to compensate for the shortcomings of existing remote models of practical education.	Experimental	The researchers posit that those students who were using VR and Metaverse methods in the classroom, scored higher than others that relied on other remote models. They note that their research participants felt comfortable using the Metaverse.
Lee and Hwang	2022	Sustainability (Switzerland)	The research investigates multi-dimensional aspects of the teachers' readiness to design technology-enhanced learning environments. It documents the experiences of pre-service English teachers in instructional virtual reality (VR) and	Quantitative	The researchers suggest that VR's transformative experiences are conducive to capacitate pre-service teachers' technological readiness, 4Cs (Critical Thinking, Creativity, Collaboration, Communication) in digital citizenship. They report

			examines how their VR creation can be linked to a Metaverse platform for learning adaptivity and sustainable education.		their pedagogical benefits associated with the Metaverse.
Lee *et al.*	2022a	JMIR Research Protocols	This research aims to develop and apply a Metaverse-based child social skills training program aimed at improving the social interaction abilities of children aged 7-12 years, diagnosed with autism spectrum disorder (ASD).	Experimental	The researchers imply that their Metaverse-based Program for the Education and Enrichment of Relational Skills (PEERS) can improve the social skills of children with ASD.
Lee *et al.*	2022b	Computers, Materials and Continua	This research explores user satisfaction levels with the Metaverse through machine learning.	Quantitative	The researchers report the benefits of using a Valence Aware Dictionary and Sentiment Reasoner (VADER). They indicate that the Light Gradient Boosting Machine (LightGBM), and the Term Frequency-Inverse Document Frequency (TF-IDF) has the highest accuracy (of 88.68%) among other models.
Li *et al.*	2022	Wireless Networks	This research investigates how artificial intelligence (AI) and the Metaverse's mobile internet technologies can be used to improve the teaching quality of football	Experimental	The researchers imply that the use of a 360-degree panoramic virtual reality (VR) can improve the teaching quality of footballers. They argue that the reconstruction of a football teaching environment is beneficial to promote the combination of football teaching and smart learning.
Lu *et al.*	2022	Optics Express	This research proposes an augmented reality (AR) 3D display based on a pixelated volume holographic optical element, that can be used in different contexts, including in education.	Experimental	The researchers suggest that their prototype (i.e. a compact glasses-free AR 3D display), can be used as window displays, exhibitions, in remote education and/or for teleconferencing purposes.
Ng	2022	Australasian Journal of Educational Technology	This research provides an exploratory review that conceptualizes the Metaverse.	Review	The researcher identifies four dimensions of the Metaverse including immersion, socialization, decentralization and advanced computing. He proposes a research model that connects key elements of the Metaverse and puts forward his implications to policy makers, educators and researchers.
Njoku *et al.*	2023	IET Intelligent Transport Systems	This research introduces the readers to the key concepts of the Metaverse. Afterwards, it focuses on data driven intelligent transportation systems (DDITS).	Review and case studies	The researchers discuss on two case studies, (i) the invisible to visible (I2V) and on (ii) the Metaverse on Wheels (MoW) technologies. They elaborate on security and network issues with regards to DDITS.

Nurhidayah *et al.*	2020	Asian EFL Journal	This research utilizes augmented reality (AR) and the Metaverse to evaluate the students' problem analyses.	Experimental	The researchers contend that the application of a systemic approach to problem solving can enhance the students' learning outcomes.
Park and Kim	2022	Sustainability (Switzerland)	This research explores the relevant literature on educational gaming experiences and on learning motivations through the Metaverse.	Review	The researchers commend that educators ought to use learning games through the Metaverse. They identify five types of games that can be used in the realms of education.
Petrigna and Musumeci	2022	Journal of Functional Morphology and Kinesiology	This research reviews the extant literature related to the use of the Metaverse, for the promotion of health education and training.	Review	The researchers infer that the Metaverse can be utilized to develop proper health promotion programs and standardized training.
Ramesh *et al.*	2022	Indian Journal of Ophthalmology	This research develops four-dimensional (4D) ophthalmic holograms.	Experimental	The researchers argue that extended reality (XR) enhances the real world with immersive cinematic and photoreal experiences. They indicate that their holograms can be enhanced and controlled by touch.
Ratten	2023	International Journal of Management Education	This research explores how and why teaching and learning methods through digital technologies can be used in a post COVID-19 pandemic era.	Review	The researcher implies that COVID-19 has led to changes in the provision of management education. She envisages that educators will be placing more emphasis on delivering interactive experiences by using games and simulations in the Metaverse, through work/life balance and via remote learning.
Ryu *et al.*	2022	IEEE Access	This research describes a system model that is intended to guarantee secure communications in Metaverse environments, by using the Blockchain's digital ledger technologies.	Experimental	The researchers argue that their proposed system model can be used to improve the security in Metaverse environments. It also explains how mutual authentication schemes that rely on biometric information and Elliptic Curve Cryptography (ECC) could provide secure communications between users and platform servers.
Seddon *et al.*	2023	Current Opinion in Ophthalmology	This research summarizes recent technological advancements in medical and surgical education. It discusses about the future of medicine, on blockchain technologies, the Metaverse, and on Web3.	Discursive	The researchers imply that 3D live streaming has the potential to revolutionize ophthalmic education by removing traditional geographic and physical constraints of in-person surgical viewing. They maintain that the Metaverse and Web3 technologies will improve how practitioners operate, teach, learn, and transfer knowledge.

Siyaev and Jo	2021a	Sensors	The researchers use mixed reality technologies (including smart glasses) to teach trainee engineers about the aircraft maintenance of a Boeing 737. They rely on a deep learning speech interaction module to control virtual assets (by using speech commands), that enable them to operate with both hands.	Experimental	The results show that a speech interaction model can accurately recognize commands along with the language, on the F1-Score metric for command and language prediction. The researchers suggest that their proposed speech interaction module (that uses the Metaverse), can improve the aircraft maintenance training of trainee engineers.
Siyaev and Jo	2021b	IEEE Access	This research investigates the use of the Metaverse for aircraft maintenance training and education of Boeing-737. The authors explain that the training through the Metaverse includes access to legacy manuals, 3D models, 3D simulators, and aircraft maintenance knowledge.	Experimental	The researchers suggest that the proposed Aircraft Maintenance Metaverse is a cheap and scalable solution for aviation colleges since it replaces expensive physical aircraft with virtual ones, that can be easily modified and updated.
Skalidis *et al.*	2022	Trends in Cardiovascular Medicine	This research sheds light on CardioVerse: The authors elaborate on the cardiovascular medicine in the era of the Metaverse.	Discursive	The researchers imply that CardioVerse applications can be used to enhance medical visits, cardiovascular interventions and in medical education. They elaborate on different challenges, including security, technical, legislative and regulatory issues.
Suh and Ahn	2022	Journal of Intelligence	This research analyzes the learners' experiences and attitudes toward the Metaverse. The researchers rely on a constructivist perspective.	Quantitative	The researchers report that, on average, 97.9% of elementary school students had positive experiences with the Metaverse. Most of them indicate that it is closely related to their everyday life.
Sunardi *et al.*	2022	Bulletin of Electrical Engineering and Informatics	This research investigates the use and acceptance of augmented reality (AR) during video conferences (for educational purposes).	Quantitative	The researchers confirm that performance expectancy, hedonic motivation, and habitual usage can influence the users' acceptance of AR Technologies. Other factors including effort expectancy, social influence as well as facilitating conditions could also have a significant impact on their acceptance, albeit to a lower effect.
Tan *et al.*	2022	Asia-Pacific Journal of Ophthalmology	This research is focused on the use of Metaverse for the provision of virtual health care services in Ophthalmology.	Discursive	The researchers elaborate on virtual health and on the Metaverse. They discuss about their benefits and identify possible challenges including cybersecurity risks, sparse internet connectivity, lack of technology literacy and on the usability of

					such technologies among visually impaired individuals.
Tlili *et al.*	2022	Smart Learning Environments	This research presents a systematic literature review focused on the Metaverse in education.	Review / bibliometric analysis	The researchers indicate that the Metaverse can be used to improve teaching and learning experiences.
Wang *et al.*	2022	IEEE Transactions on Learning Technologies	This research investigates how the Metaverse can be utilized to design innovative learning environments.	Discursive	The researchers imply that the Metaverse ecosystem comprises four major hubs: 1) knowledge hub; 2) instructional design and performance technology hub; 3) talent and training hub; and 4) research and technology hub. They argue that these hubs necessitate an appropriate infrastructure, an equitable access to the technology and a secure connection.
Wu and Ho	2023	Australasian Emergency Care	This research is focused on the application of the Metaverse in acute medicine.	Review	The researchers argue that augmented reality (AR) and virtual reality (VR) integration have broad applications in education and clinical training. They point out that lifelogging and the mirror world are still developing fields of the metaverse.
Xi *et al.*	2023	Information Systems Frontiers	This research explores whether extended reality (XR) technologies, specifically Augmented Reality (AR) and Virtual Reality (VR), could increase or decrease the difficulties of carrying out everyday tasks.	Experimental	The researchers find that AR is significantly related to overall workload, especially to mental demand and effort. They report that VR has no significant effect on any workload sub-dimensions.
Yang *et al.*	2022	Clinical eHealth	This research discusses about the use of the Metaverse in medicine.	Discursive	The researchers indicate that they can utilize the Metaverse for medical education, science popularization, consultation, graded diagnosis and treatment, as well as for clinical research.
Yu	2022	Technologies	This research explores how the Metaverse can be used to improve the learning outcomes of physical education.	Discursive	The researcher implies that there are four types of the Metaverse including augmented reality, lifelogging, mirror world and the virtual world.
Zhang *et al.*	2022a	Frontiers in Psychology	This research sheds light on the use of the Metaverse in education. It describes its origin, provides definitions, and explains its shared features.	Discursive	The researchers identify four potential applications of the metaverse in education including blended. learning, language learning, competence-based education, and inclusive education. They also discuss about the challenges of this immersive technology.

Zhang *et al.*	2022b	Electronics (Switzerland)	This contribution puts forward a framework for the utilization of the Metaverse for the promotion of cultural heritage.	Discursive	The researchers identify five different dimensions including linearity, planarity, space, time and context, to better understand how the Metaverse could add value to the cultural heritage.
Zhao *et al.*	2022	Frontiers in Public Health	This systematic study provides useful insights into the overall application of virtual reality technology in the study of nursing.	Review / bibliometric analysis	The researchers suggest that virtual nursing has had an impact on both nurses and clients. They contend that the research and application of virtual reality technology will probably increase with the emergence of the Metaverse.
Zhou	2022	Mobile Information Systems	This paper is focused on the smart education ecosystem. It describes three education scenarios including resource collaborative interaction, virtuality-reality integration experience, and ubiquitous spatial inquiry.	Discursive	The researcher implies that a smart education ecosystem relies on resource ecology, interaction ecology, space ecology, and collaboration ecology.

Note: This list features fifty (50) of the most cited articles indexed in Scopus. They are sorted in alphabetical order, as at 30th April 2023.

Table 1 indicates that most of the articles (i.e. 32%) that were captured through this review relied on secondary research methodologies. They were discursive and presented theoretical or conceptual contributions. Other publications have used different research designs, including experimental (30%); reviews including bibliometric studies (22%); quantitative (12%); descriptive (2%); and sentiment analysis (2%). These findings suggest that, to date, there were no qualitative studies on the use of the Metaverse in education.

2.4 Synthesis

2.4.1 Identification of keywords and of relevant themes associated with Metaverse in education

This review suggests that a number of commentators shed light on various aspects about Metaverse technologies, including on their personalization (Bühler *et al.*, 2022; Chen, 2022; Díaz, 2020; Park, and Kim, 2022) and interactivity features (Cortés Rodríguez *et al*., 2022, Guo and Gao, 2022; Lee *et al.*, 2022; Ratten, 2023; Siyaev and Jo, 2021a), as well as on their gaming attributes (Barry *et al*., 2015; Díaz *et al*., 2020; Estudante and Dietrich, 2020; Garrido-Iñigo and Rodríguez-Moreno, 2015; Melendez Araya and Hidalgo Avila, 2018; Park and Kim, 2022), among other issues. Various authors classified the Metaverse into four categories: (i) augmented reality (Dwivedi *et al*., 2022; Hwang and Chien, 2022; Kye *et al.,* 2021), (ii) lifelogging (Kye *et al*., 2021; Tlili *et al*., 2022; Xu *et al*., 2023), (iii) mirror world (Guo and Gao, 2022; Kye *et al*., 2021; Tlili *et al*., 2022), and (iv) virtual reality (Dwivedi *et al*., 2022; Hwang and Chien 2022; Kye *et al*., 2021; Ng, 2022; Yu, 2022).

For example, Kye et al. (2021) differentiated between ‘augmentation’ and ‘simulation’. They argued that whilst augmentation technology augments the physical environment with virtual

objects, the simulation technology provides an immersive environment that re-models the users' perceptions of reality. In addition, Kye et al. (2021) contended that the Metaverse comprises an inner world as well as an external world. They hinted that the inner world represents the individual users' identities as they can utilize an avatar as an interface to engage in behaviors and actions while they are navigating through the Metaverse. On the other hand, they suggested that the external world is related to reality aspects including to the 3D displays of the Metaverse's virtual environment.

Table 2 features a summary of the most listed keywords related to the Metaverse technologies in the educational context. It identifies the contributing authors and appraises their work, as they elaborated on these notions.

Table 2. Keywords related to the adoption of the Metaverse (developed by the author)

Keyword	**Contributing author(s)**
Artificial intelligence	Hwang and Chien (2022); Tan *et al.* (2022); Tlili *et al.* (2022).
Augmented reality	Dwivedi *et al.* (2022); Hwang and Chien (2022); Kye *et al.* (2021).
Avatar	Almarzouqi *et al.* (2022); Dwivedi *et al.* (2022); Tlili *et al.* (2022).
Blockchain	Bansal *et al.* (2022); Ryu *et al.* (2022).
Cyberspace	Guo and Gao (2022); Ratten (2023).
Digital twin	Siyaev (2021b); Tlili *et al.* (2022); Zhang *et al.* (2022a).
Extended reality	Dwivedi *et al.* (2022); Zhang *et al.* (2022a).
Immersive learning	Dwivedi *et al.* (2022).
Internet of things	Bansal *et al.* (2022).

Lifelogging	Kye *et al.* (2021); Tlili *et al.* (2022); Xu *et al.* (2023).
Metaverse	Dwivedi *et al.* (2022); Hwang and Chien (2022); Xi *et al.* (2023).
Mirror world	Guo and Gao (2022); Kye *et al.* (2021); Tlili *et al.* (2022).
Mixed reality	Siyaev (2021a); Siyaev (2021b); Xi *et al.* (2023).
Non-fungible tokens	Bansal *et al.* (2022).
Three dimensional displays	Dwivedi *et al.* (2022); Hwang and Chien (2022); Kye *et al.* (2021).
Virtual classroom	Hwang and Chien (2022); Kye *et al.* (2021); Tlili *et al.* (2022).
Virtual reality	Dwivedi *et al.* (2022); Hwang and Chien (2022); Kye *et al.* (2021).
Virtual worlds	Dwivedi *et al.* (2022); Jovanović and Milosavljević (2022); Tlili *et al.* (2022).

2.4.2 How, why, where and when is the Metaverse being used for educational purposes?

Currently, individuals can access the Metaverse's virtual space through the worldwide web. They can enhance their online experiences with this interactive technology, especially if they utilize VR and AR technologies (Nurhidayah *et al.,* 2020; Marini *et al.,* 2022). Like VR, the Metaverse is an immersive rather than static (Kye *et al.,* 2022; Park *et al.,* 2021). It differentiates itself from other digital media including social media. Many researchers speculate that in the foreseeable future it could enable individuals to perform most of the activities they do in everyday life (Dwivedi *et al.,* 2022). They anticipate that online users can switch through different locations in the Metaverse with a simple gesture, as everything is connected and accessible in an interoperable digital world (as opposed to mobile applications and online browsers).

Online users can use the Metaverse to create/change user-generated content, to interact with other avatars, improve their work productivity, play games, make transactions with businesses, and may even use its applications for educational purposes (Hwang and Chien, 2022; Xi *et al.,* 2023). Some of its latest interfaces enable individuals to visit 'virtual worlds', and to move around in them, through an electronic avatar, that can be customized according to their preferences (Díaz, 2020; Jovanović and Milosavljević, 2022; Park *et al.,* 2021; Tlili *et al.,* 2022). Elaborate avatars could mimic personal gestures and expressions (Almarzouqi et al., 2022). They are intended to enhance the online users' sense of presence and to create emotional realism (Tlili *et al.,* 2022) in virtual settings, that could ultimately benefit individuals, and their communications with others, in various contexts (Lin and Chu, 2021).

This review revealed that a few researchers are already experimenting with different Metaverses to create virtual environments for educational purposes (Díaz *et al.,* 2020; Guo and Gao, 2022; Li *et al.*, 2022; Ryu *et al.* 2022; Siyaev and Jo, 2021a; Siyaev and Jo, 2021b; Xi *et al.,* 2023). It clearly indicated that the Metaverse can be used to teach different topics, including agriculture (Khansulivong *et al*., 2022), chemistry and structural biology (Cortés Rodríguez *et al*., 2022), geography (Melendez Araya and Hidalgo Avila, 2018), languages (Guo and Gao, 2022; Siyaev and Jo, 2021a), medicine (Almarzouqi *et al*., 2022; Huh, 2022; Skalidis et al, 2022), nursing (Zhao et al., 2022); physical education and sports (Li et al., 2022) and sustainability (Hadjistassou, 2016; Lee and Hwang. 2022; Park and Kim, 2022). It could be also be used in primary educational settings (Suh and Ahn, 2022), as well as in the training and development in workplace environments, including within the aviation industry (Siyaev and Jo, 2021a; Siyaev and Jo, 2021b).

Some course designers and educators are using OpenSimular project, Meta Quest's Oculus VR systems (Girard and Robertson, 2020) or Second Life (Dwivedi *et al*., 2021). In many cases,

they commend that the Metaverse's learning applications are providing immersive experiences to our students (Dwivedi *et al.,* 2022; Makransky and Mayer, 2022; Melendez Araya and Hidalgo Avila, 2018).

3. Discussion

A critical review of the literature suggests that there are both pros and cons of using the Metaverse applications in education. Table 3 provides a summary of possible costs and benefits of delivering education through the Metaverse's virtual environments. The following section features a more detailed discussion on these elements.

Table 3. A cost-benefit analysis on Metaverse education (developed by the author)

Costs	Benefits
Infrastructure, resources and capabilities	Immersive multi-sensory experiences in 3D environments
The degree of freedom in a virtual world	Equitable and accessible space for all users
Privacy and security of users' personal data	Interactions with virtual representations of people and physical objects
Identity theft and hijacking of user accounts	Interoperability
Borderless environment raises ethical and regulatory concerns	
Users' addictions and mental health issues	

3.1 Costs

3.1.1 Infrastructure, resources and capabilities

The use of the Metaverse technology will probably necessitate a thorough investment in hardware to operate in the universities' virtual spaces. It requires intricate devices, including appropriate high-performance infrastructures to achieve accurate retina display and pixel density for realistic virtual immersions. These systems rely on fast internet connections with good bandwidths as well as computers with adequate processing capabilities, that are equipped with good graphic cards (Bansal *et al*., 2022; Chang *et al.*, 2022; Girard and Robertson, 2020; Makransky and Mayer 2022). For the time being, VR, MR and AR hardware may be considered as bulky, heavy, expensive and cost-prohibitive, in some contexts.

3.1.2 The degree of freedom in a virtual world

The Metaverse may offer higher degrees of freedom than what is available through the worldwide web and web2.0 technologies (Hackl *et al.,* 2022). Its administrators cannot be in a position to anticipate the behaviors of all persons using their technologies. Therefore, Metaverse users including students as well as their educators, can possibly be exposed to positive as well as to negative influences, as other individuals can disguise themselves, by using anonymous avatars, to roam in the vast virtual environments.

3.1.3 Privacy and security of users' personal data

The users' interactions with the Metaverse as well as their personal or sensitive information, can be tracked by platform operators hosting this Internet service, as they continuously record, process and store their virtual activities in real-time. Like its preceding

worldwide web and Web 2.0 technologies, the Metaverse can possibly raise the users' concerns about the security of their data and of their intellectual properties (Chen, 2022; Ryu *et al.* 2022l; Skalidis *et al.,* 2022). They may be wary about data breaches, scams, et cetera (Njoku *et al*., 2023; Tan *et al.,* 2022).

Public blockchains and other platforms can already trace the users' sensitive data, so they are not anonymous to them. Individuals may decide to use one or more avatars to explore the Metaverse's worlds. They may risk exposing their personal information, particularly when they are porting from one Metaverse to another and/or when they share transactional details via non-fungible token (NFTs) (Hwang, 2023). Some Metaverse systems do not require their users to share personal information when they create their avatar. However, they could capture relevant information from sensors that detect their users' brain activity, monitor their facial features, eye motion and vocal qualities, along with other ambient data pertaining to the users' homes or offices.

They may have legitimate reasons to capture such information, in order to protect them against objectionable content and/or unlawful conduct of other users. In many cases, the users' personal data may be collected for advertising and/or for communication purposes. Currently, different jurisdictions have not regulated their citizens' behaviors within the Metaverse contexts. Works are still in progress, in this regard.

3.1.4 Identity theft and hijacking of user accounts

There may be malicious persons or groups who may try use certain technologies, to obtain the personal information and digital assets from Metaverse users. Recently, a deepfake artificial intelligence software has developed short audible content, that mimicked and impersonated a human voice. Other bots may easily copy the human beings' verbal, vocal and visual data including

their personality traits. They could duplicate the avatars' identities, to commit fraudulent activities including unauthorized transactions and purchases, or other crimes with their disguised identities. For example, Roblox users reported that they experienced avatar scams in the past. In many cases, criminals could try to avail themselves of the digital identities of vulnerable users, including children and senior citizens, among others, to access their funds or cryptocurrencies (as they may be linked to the Metaverse profiles). As a result, Metaverse users may become victims of identity theft. In the near future, evolving security protocols and digital ledger technologies like the blockchain will be increasing the transparency and cybersecurity of digital assets (Ryu *et al.,* 2022). However, users still have to remain vigilant about their digital footprint, to continue protecting their personal information.

As the use of the virtual environment is expected to increase in the coming years, particularly with the emergence of the Metaverse, it is imperative that new ways are developed to protect all users including students. Individuals ought to be informed about the risks to their privacy. Various validation procedures including authentication, such as face scans, retina scans, and speech recognition may be integrated in such systems to prevent identity theft and hijacking of Metaverse accounts.

3.1.5 Borderless environment raises ethical and regulatory concerns

For the time being, a number of policy makers as well as academics are raising their questions on the content that can be presented in the Metaverse's virtual worlds, as well as to how they can control the conduct and behaviors of the Metaverse users. Arguably, it may prove difficult for the regulators of different jurisdictions to enforce their legislation in the Metaverse's borderless environment (Njoku *et al.,* 2023). For example, European citizens are well acquainted with the

European Union's (EU) General Data Protection Regulation (GDPR, 2016). Other countries have their own legal frameworks and/or principles that are intended to safeguard the rights of data subjects as well as those of content creators. For example, the United States governments has been slower that the EU to introduce its privacy by design policies. Recently, the South Korean Government announced a set of laudable, non-binding ethical guidelines for the provision and consumption of metaverse services. However, currently, there aren't a set of formal rules that can apply to all Metaverse users.

3.1.6 Users' addictions and mental health issues

Although many AR and VR technologies have already been tried and tested in the past few years, the Metaverse is still getting started. At the moment, it is difficult to determine what are the effects of the Metaverse on the users' health and well-being (Chen, 2022). Many commentators anticipate that an unnecessary exposure to Metaverse's immersive technologies may result in negative side-effects for the psychological and physical health of human beings (Han *et al.,* 2022). They are suggesting that individuals may easily become addicted to a virtual environment, where the limits of reality are their own imagination. They are lured to it "for all the things they can do" and will be willing to stay "for all the things they can be" (these are excerpts from Ready Player One, a movie blockbuster).

Past research confirms that spending excessive time on internet, social media or playing video games can increase the chances of mental health problems like attention deficit disorders (Dullur *et al.,* 2021), as well as anxiety, stress or depression (Lee *et al.,* 2021), among others. Individuals play video games to achieve their goals, to advance to the next level. Their gameplay releases dopamine (Pallavicini and Pepe, 2020). Similarly, their dopamine levels can increase

when they are followed through social media, or when they receive likes, comments or other forms of online engagements (Capriotti *et al.,* 2021; Camilleri and Kozak, 2022; Troise and Camilleri, 2021). Individuals can easily develop an addiction to this immersive technology, as they seek stimulating and temporary pleasurable experiences in its virtual spaces. As a result, they may become dependent to it (Burhan and Moradzadeh, 2020).

However, the individuals' interpersonal communications via social media networks are not as authentic or satisfying as real-life relationships, as they are not interacting in-person with other human beings. In the case of the Metaverse, their engagement experiences may appear to be real. Yet again, in the Metaverse, its users are located in a virtual environment, they not physically present near other individuals. Human beings need to build an honest and trustworthy relationship with one another. The users of the Metaverse can create avatars that could easily conceal their identity within the virtual world.

3.2 Benefits

3.2.1 Immersive multi-sensory experiences in 3D environments

The Metaverse could provide a smooth interaction between the real world and the virtual spaces. Its users can engage in activities that are very similar to what they do in reality. However, it could also provide opportunities for them to experience things that could be impossible for them to do in the real world. Sensory technologies enable users to use their five senses of sight, touch, hearing, taste and smell, to immerse themselves in a virtual 3D environment.

Many students are experienced gamers and are lured by their 3D graphics. They learn when they are actively involved (Siyaev and Jo, 2021a). Therefore, the learning applications should be as meaningful, socially interactive and as engaging as possible (Camilleri and Camilleri, 2019).

The Metaverse's VR tools can be entertaining and could provide captivating and enjoyable experiences to their users (Bühler *et al*., 2022; Hwang, 2023; Suh and Ahn, 2022). In the past years, a number of educators and students have been using 3D learning applications (e.g. like Second Life) to visit virtual spaces that resemble video games (Hadjistassou, 2016).

Arguably, there is scope for educators and content developers to create digital domains like virtual schools, colleges and campuses, where students and teachers can socialize and engage in two-way communications. Students could visit the premises of their educational institutions in online tours, from virtually anywhere. A number of universities are replicating their physical campus with virtual ones (Díaz *et al*., 2020). The design of the virtual campuses may result in improved student services, shared interactive content that could improve their learning outcomes, and could even reach wider audiences. Previous research confirms that it is more interesting and appealing for students to learn academic topics through the virtual world (Lu *et al*., 2022).

3.2.2 Equitable and accessible space for all users

Like other virtual technologies, the Metaverse could be accessed from remote locations. Educational institutions can use its infrastructure to deliver courses (free of charge or against tuition fees, as of now). Metaverse education may enable students from different locations to use its open-source software to pursue courses from anywhere, anytime. Hence, its democratized architecture could reduce geographic disparities among students, and increases their chances of continuing education through higher educational institutions in different parts of the world.

In the future, students including individuals with different abilities, may use the Metaverse's multisensory environment to immerse themselves in engaging lectures (Hutson, 2022; Lee *et al.,* 2022a).

3.2.3 Interactions with virtual representations of people and physical objects

Currently, individual users can utilize the AR and VR applications to communicate with others and to exert their influence on the objects within the virtual world. They can organize virtual meetings with geographically distant users, attend conferences, et cetera (Camilleri and Camilleri, 2022b; Yu, 2022). Various commentators indicate that the Metaverse can be used to learn academic subjects in real-time sessions in a VR setting (Saritas and Topraklikoglu, 2022; Singh *et al*., 2022). It could be utilized to interact with peers and course instructors. The students and their lecturers will probably use an avatar that will represent their identity in the virtual world. Many researchers noted that avatars facilitate interactive communications and are a good way to personalize the students' learning experiences (Barry *et al*., 2015; Díaz, 2020; Garrido-Iñigo and Rodríguez-Moreno, 2015; Melendez Araya and Hidalgo Avila, 2018; Park, and Kim, 2022).

3.2.4 Interoperability

Many commentators speculate that unlike other VR applications, the Metaverse could probably enable its users to retain their identities as well as the ownership of their digital assets through different virtual worlds and platforms (Hwang, 2023; Xu *et al.,* 2022). This implies that Metaverse users can communicate and interact with other individuals in a seamless manner through different devices or servers, across different platforms. They may be in a position to use the Metaverse to share data and content in different virtual worlds via Web 3.0 (Seddon *et al.,* 2023).

4. Conclusion

This research theorizes about the pros and cons of using Metaverse's immersive applications for educational purposes. It clearly indicates that many academics are already experimenting with VR's immersive technology. While some of them anticipate that the Metaverse is poised to transform education as they envisage that it could be integrated with school curricula and in their educational programs. Others are more skeptical about the hype around this captivating technology. Time will tell whether the Metaverse project comes to fruition.

For the time being, education stakeholders are invited to untap the potential of AR and VR technologies to continue improving the students' learning journeys. Of course, further research is required to better understand how policy makers as well as practitioners including the developers of the Metaverse, can address the number of challenges and issues identified in this contribution.

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