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Smart Learning Environments

REVIEW

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Is Metaverse in education a blessing or a curse: a combined content and bibliometric analysis

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Abstract

The Metaverse has been the centre of attraction for educationists for quite some time. This field got renewed interest with the announcement of social media giant Facebook as it rebranding and positioning it as Meta. While several studies conducted literature reviews to summarize the findings related to the Metaverse in general, no study to the best of our knowledge focused on systematically summarizing the finding related to the Metaverse in education. To cover this gap, this study conducts a systematic literature review of the Metaverse in education. It then applies both content and bibliometric analysis to reveal the research trends, focus, and limitations of this research topic. The obtained findings reveal the research gap in lifelogging applications in educational Metaverse. The findings also show that the design of Metaverse in education has evolved over generations, where generation Z is more targeted with artificial intelligence technologies compared to generation X or Y. In terms of learning scenarios, there have been very few studies focusing on mobile learning, hybrid learning, and micro learning. Additionally, no study focused on using the Metaverse in education for students with disabilities. The findings of this study provide a roadmap of future research directions to be taken into consideration and investigated to enhance the adoption of the Metaverse in education worldwide, as well as to enhance the learning and teaching experiences in the Metaverse.

Keywords: Metaverse, Cyber worlds, Virtual worlds, Avatar, Artificial intelligence, Digital twin, Mirror world

Introduction

Metaverse in education

The idea of the Metaverse is not brand-new, in contrast, it was heard earlier in sci-fi novels such as Snow Crash (Stephenson, 1992) and drew some attention with the movie version of the novel entitled Ready Player One (Cline, 2011). There were already known and popular examples such as Second Life and the massively multiplayer online role-playing game World of Warcraft which attracted attention of millions (Wiederhold, 2022). However, when Mark Zuckerberg officially announced the Metaverse project in October 2021, Metaverse became a buzzword. Many educators and researchers started providing several future agendas and implementation scenarios in their learning practices. The increasing interest in the educational landscape may stem from a wide range of possibilities including the virtual space that offers real-like representations of selves which possibly enhance the social aspect of teaching and learning. However, the term is relatively new and there is a need to examine the state-of-the-art of the research on Metaverse and this is where this study steps in.

Metaverse is a combination of the prefix "meta" which implies transcending with the word "universe" which describes a parallel or virtual environment linked to the physical world. Metaverse was first coined in 1992 by Neal Stephenson in his science-fiction novel Snow Crash, which envisions a virtual reality-based successor to the Internet. In this novel, people try to escape the pain of the real world by exploring a digital world through several digital avatars (Stephenson, 1992). Since then, it has been defined and considered differently, including collective space in virtuality (Lee et al., 2021), mirror world (Lee et al., 2021), embodied internet/spatial Internet (Chayka, 2021), a new type of Internet application and social form that integrates a variety of new technologies (Ning et al., 2021), post-reality universe, a perpetual and persistent multiuser environment merging physical reality with digital virtuality (Mystakidis et al., 2021), an omniverse: a venue of simulation and collaboration (Lee et al., 2021), and lifelogging (Bruun, & Stentoft, 2019).

Go and his colleagues, as cited in Kye et al. (2021), defined Metaverse as "a 3D-based virtual reality in which daily activities and economic life are conducted through avatars representing the real themselves." Lee and his colleagues, as cited in Kye et al. (2021), further stated that "Metaverse means a world in which virtual and reality interact and co-evolve, and social, economic, and cultural activities are carried out in it to create value." These two definitions imply that the Metaverse does not simply combine the physical and virtual worlds; it is instead a continuity of the physical world in the virtual world to create an ecosystem that merges both worlds (physical and virtual). Supporting the idea that Metaverse is an ecosystem and emphasizing its scope, Knox (2022) also highlights that the Metaverse "is not simply a platform developed by one company, implying the usual constraints of monopolisation, but rather a new plane of existence, not just void of control by any single corporation, but also free of incursions by any state entity or government." (p. 4). Hwang and Chien (2022) proposed a framework to differentiate the Metaverse from AR and VR in three features: "shared," "persistent," and "de-centralized.", emphasizing that AR and VR could be used in Metaverse with other elements besides the experiencing time and implementing of AI technology. Therefore, Metaverse provides the possibilities of immersion experience, collaborations, and interaction that supports developing social experience allowing "parallel world[s]" to emerge (Schlemmer, & Backes, 2015). Lee et al. (2021) further mentioned that developing Metaverse requires three stages, namely: (1) digital twins where digital models and representations of the physical world can be created. Digital twins are basically virtual replicas of physical environments that are synchronously used; (2) Individuals with high digital competencies which require people to have expertise in technology to manage and work in the digital environment; and, (3) co-existence of physical-virtual which implies merging and connecting the virtual and physical environment. Furthermore, Davis et al. (2009) developed a model for research in Metaverses including five components: (1) the Metaverse itself, (2) people/avatars, (3) Metaverse technology capabilities, (4) behaviours, and (5) outcomes.

In education, the Metaverse is also not a new concept as several researchers and educators have discussed its implications for learning. For instance, a study by Kemp and Livingstone in (2006) discussed how to combine Metaverse through the use of a virtual world called "Second Life" with learning management systems to enhance the learning process (Kemp & Livingstone, 2006). Collins (2008), focusing on virtuality dimension, argued that the Metaverse can be the next space where individuals can meet and socially interact requiring higher education to be proactive for using it teaching and learning purposes. It is also argued that the 3D digital virtual world offers interaction and communication through using avatar which reflects on the feeling of presence (Schlemmer, & Backes, 2015). Additionally, in 2006, a summit at the Stanford Research Institute International was held to draw a roadmap for the future of the Metaverse technology. Academics from different domains, technology architects, entrepreneurs, and futurists took part to envision and forecast a 10 years plan about how the internet would look in the future (Metaverse Roadmap Summit, 2006).

Though the roadmap was techno-centric, Kye et al. (2021) presented an educational definition (with possibilities and limitations) of the 4 types of the Metaverse proposed from the Roadmap Summit. According to Fig. 1, there are four categories of Metaverse technology, namely: Augmented Reality (AR), Lifelogging, Mirror Worlds, and Virtual Worlds. The four categories are characterized by the two axes: Augmentation versus Simulation (A vs. S) and External versus Intimate (E vs I). For the Augmentation technology, a new visual function is added to the existing environment by superimposing digital information on the physical world that we perceive. In contrast, the Simulation

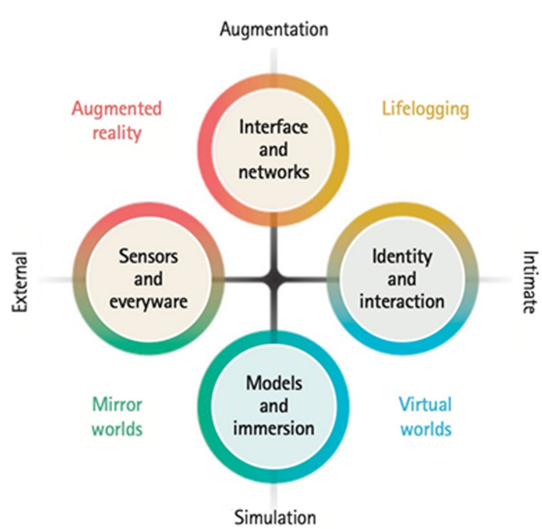


Fig. 1 A diagram of the 4 types of Metaverse according to Metaverse Roadmap Summit (Kye et al., 2021) (CC BY 4.0)

technology generates and manipulates models of the existing physical environment and creates virtual interactions and experiences. The other division deals with external/internal worlds. For the External world, the technology focuses on the users' external environment by displaying information about the surroundings and how to control them. In contrast, the Intimate world uses technology that focuses on the identity and behaviour of individuals or objects by creating inner worlds of avatars or digital profiles where users have agency in the digital environment. The results of the integrations of these two axes produced four types of the Metaverse. In the Augmented Reality Metaverse, the technology features building smart environments that are based on location networks such as in *Pokémon Go*. For Lifelogging Metaverse, the technology features recording everyday information about people or objects using AR technology for *Facebook* or *Instagram* for example. In Mirror Worlds' Metaverse, the technology builds virtual maps and models using GPS technology on apps such as *Google Earth* or *Google Maps*. For the Virtual Worlds' Metaverse, the technology is based on avatars interacting virtually and reflecting different personas.

The advent of immersive technologies, including Virtual Reality (VR), Mixed Reality (MR), Augmented Reality (AR), and Extended Reality (XR) has further promoted Metaverse in several educational applications. One of the Metaverse's advantages is enabling students to attend their classes virtually and providing elements that are involved in the real classroom. Students in Metaverse can interact with teachers and communicate with classmates through their avatars. This can create an immersive learning opportunity that enhances the students' learning motivation. For instance, Siyaev and Jo (2021b) investigated the use of mixed reality in maintenance to provide an engaging learning experience for aircraft maintenance. González Crespo et al. (2013) analyzed educational virtual environment applications and the dissemination of knowledge in the form of free courses in the Metaverse using OpenSim. Reyes (2020) developed a Metaverse using AR and mobile learning for teaching mathematics. The findings showed that the application of Metaverse in mathematics can enhance students' learning outcomes. Furthermore, Park and Kim (2022b) identified the world types in educational Metaverse, i.e., survival, maze, multi-choice, racing/jump, and escape room world types were identified.

Research gap and study objectives

The current concept of the Metaverse is based on Generation Z's social values that the online self is no different from the ideal self (Duan et al., 2021). In other words, it is assumed that online digital identities are a reflection and representation of the real identities of the offline physical worlds. With the growth and influence of Generation Z in the Metaverse, it is now different from the Metaverse before, and, thus, it is argued that there is a need for a new definition (Park & Kim, 2022a, 2022b). Additionally, the rapid advance of mobile technology and deep learning have facilitated access to the Metaverse in anytime at anywhere compared to the early versions of the Metaverse, and improved the accuracy of vision and language recognition, resulting in more immersive environments (Park & Kim, 2022a, 2022b). Therefore, it is worth investigating the evolution of Metaverse in education, the way it is designed, and its research trends over the years.

Moreover, several literature reviews were conducted related to Metaverse in general (e.g., Narin, 2021) and reviewing graphics, interactions, and visualization studies related to Metaverse (Zhao et al., 2022); virtual commerce from both application design and consumer behaviour in Metaverse (Shen et al., 2021), digital twin (Cimino et al., 2019; Jones et al., 2020; Liu et al., 2021), 3D virtual worlds (Dionisio et al., 2013). However, no literature review, to the best of our knowledge, was conducted to summarize the findings related to Metaverse in education and provide future insights. Consequently, several questions have remained unanswered, such as which type of Metaverse, according to the roadmap Metaverse in (2006), is used in education; or what type of learning scenarios and assessment methods are conducted in the Metaverse. Therefore, to fill this gap, this study conducts a systematic literature review of Metaverse in education by adopting both bibliometric and content analysis. Bibliometric analysis was adopted to provide visual representations of the relationships between the main concepts (Yilmaz et al., 2019). This visualization through mapping allows researchers to identify the background of a given research field, the relationships between key concepts, and possible future trends (Vogel & Masal, 2015). On the other hand, content analysis was adopted to acquire an in-depth analysis of the reviewed studies – hence, to identify research themes that authors focused on while discussing Metaverse in education. Specifically, this study answers the following research questions (RQ):

RQ1 What is the trend of Metaverse in education in terms of publication year, document type, country, keywords and research methods?
RQ2 What are the types of Metaverse (according to the Metaverse roadmap in 2006) used in education?
RQ3 What is the education field and level where Metaverse was used, and which learning scenarios have been implemented?
RQ4 How the digital identity of students is represented in the Metaverse and what technologies have been used?
RQ5 How has Metaverse in education evolved over generations?
RQ6 What is the impact of the Metaverse on education and what are the associated challenges?

Method

This study combines quantitative and qualitative synthesis approaches to review the Metaverse in education studies published in the literature. A traditional systematic review is an important step before carrying out any study, however, outcome reporting bias may be introduced, and the interpretation of results is prone to be subjective in a manual review (He et al., 2017). Therefore, a mixed-methods systematic review that combines bibliometric analysis and content analysis is needed to scientifically identify the knowledge base and evolution of a topic (Tlili et al., 2022). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed to produce this systematic review (Moher et al., 2010).

To deal with this complex topic, an extensive search for research papers was conducted using the following search strings in both Web of Science and Scopus databases: Metaverse and education (Topic) OR Metaverse and learning (Topic) OR Metaverse and teaching (Topic). The data in this study include academic studies published until 31

December 2021. A study was excluded if it: (1) discusses Metaverse in general and not in education; (2) is not in English; and (3) is not accessible online. As a result, a total of 47 studies in the Web of Science database and 34 studies in the Scopus database were identified.

As part of the analysis, content analysis and bibliometric analysis were used. The data were analyzed and interpreted through these approaches for the purpose of data triangulation in order to gain a multi-dimensional perspective and increase the validity of the research. For the bibliometric analysis and synthesis, VOSviewer software was used to make distance-based co-occurrence maps: terms retrieved from keywords, titles, and abstracts were clustered and mapped according to their relatedness in a similarity matrix (Van Eck & Waltman, 2010).

Results and discussions

The obtained results are presented and discussed according to each of the aforementioned research questions.

Trends of Metaverse in education by publication year, document type, country, keywords and research method

As shown in Fig. 2, research on the use of Metaverse in education first started in 2007. The number of studies in the WOS database increased after 2008, with a peak of five studies per year in 2009, 2010, and 2013. There is a sharp decrease after 2013, and only one study was found in 2014. The maximum number of studies reached its peak with seven academic studies in 2015. After 2015, there was a decrease in the number of research papers until 2019, and it was seen that no research was conducted in 2019. Four studies were conducted each year, with a spike in 2020 and 2021. When the polynomial regression trend line is examined, it is seen that the studies on the Metaverse in the WOS database showed a fluctuating trend from 2007 to 2021 but tended to increase in recent years. When the trend line of the Scopus database is examined, it is seen that the studies on the Metaverse show a similar trend to the WOS database over the years. A

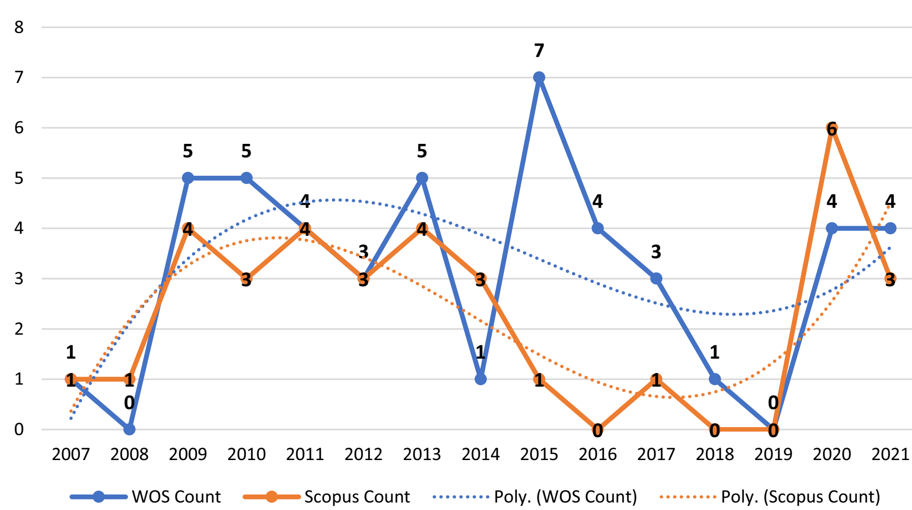


Fig. 2 Distribution of Metaverse in education research by publication year

maximum of four studies per year were conducted in the Scopus database in 2009, 2001, and 2013, and the number of studies decreased after 2013. In 2020, it showed a rapid increase with six academic studies. In 2021, the number of studies decreased, and three studies were found. It has been observed that the Metaverse research of both databases has increased in recent years, especially in the post-Covid-19 period, due to the popularity of virtual environments, the Metaverse research tends to rise again. The first wave of Metaverse research (2007–2013) can be linked to Web 2.0 and earlier examples such as Second Life. The second wave (2014–2020) can be attributed to Web 3.0 and innovative technologies such as AR/VR and the capacity increase in computing data and rendering virtual worlds. The third wave (2021 onwards) can be referred to the sudden peak in 2021 which can be explained by the investments made to the Metaverse technologies (e.g., Facebook).

In terms of the distribution of Metaverse in education research by document type, Fig. 3 shows that most publications were conference proceedings. It is seen that the number of studies in the WOS database in the article type is two times more than the Scopus database. In the book chapter genre, there are eight studies in WOS and two in Scopus. In editorial material, there are only two works in WOS. Books and review article studies have the same rate in both databases. The common feature of both databases is that there are more tendencies towards conference papers in Metaverse studies. The interest in conference papers can be explained by the faster publication processes of proceedings and the effort by academia to quickly understand the promises and potentials of Metaverse technologies.

The first author's affiliation country was considered to present the distribution of Metaverse in education research. Figure 4 shows that the United States had the highest number of research, followed by Brazil, Japan, Spain, and South Korea. Interestingly, it is seen that no research related to Metaverse in education is from the Arab or African region. This could be due to the limited infrastructure that these countries suffer from, which does not support them in adopting these technological-based learning environments (i.e., Metaverse in education). Consequently, this raises the question if this type of learning environment further emphasizes the digital divide instead of reducing it and ensuring inclusive education. There is a continuous need to investigate how developed and developing countries could work together to facilitate adopting Metaverse in

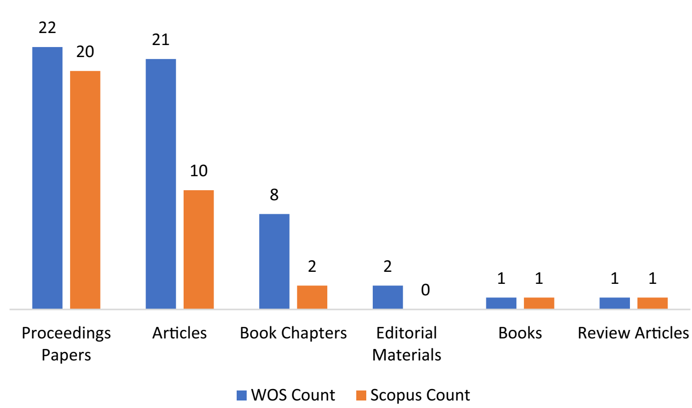
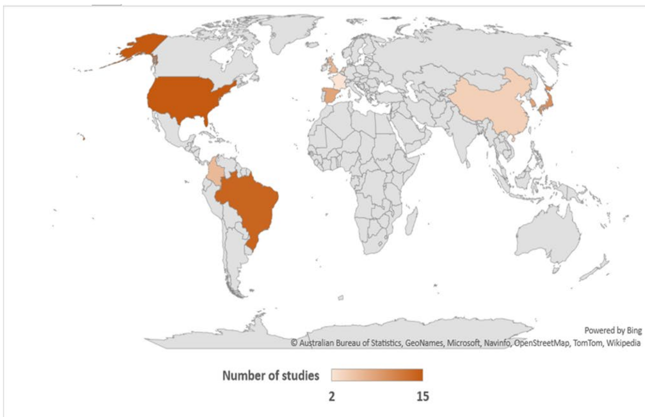


Fig. 3 Distribution of studies on Metaverse by document type



Country	Number of studies
USA	15
Brazil	14
Japan	10
South Korea	8
Spain	8
Colombia	6
United Kingdom	6
China	4
Netherlands	4
France	2

Fig. 4 Distribution of academic studies on Metaverse by country

education worldwide. There is also a continuous need to harness the power of openness and open educational resources to ensure an inclusive Metaverse in education.

When analysing Metaverse in education by study topic and according to the publication year (see Fig. 5), it is seen that the trending topics in Metaverse research are in line with time trend analysis. Accordingly, there are three thematic waves of research trends that emerged. The first wave focuses on social aspects of the Metaverse in education (see virtual worlds, virtual communities and second life in Fig. 5). The second wave explores the potentials of technology-mediated presence and immersive technologies (see Metaverse, emerging technologies, virtual environments, telepresence, avatar, augmented reality, mixed reality). The third wave unlocks the potential of self-organized AI-powered virtual learning ecologies (see deep-learning and simulation in Fig. 5).

To identify the focus and trends of Metaverse in education research, the co-occurrence of terms in keywords was analyzed using VOSviewer, as shown in Fig. 6. The size of the labels and circles depends on the number of co-occurrences. Lines identify major links between terms, and their thickness and the distance between the terms represent the association strength. For example, in Fig. 6, the terms "metaverse" and "e-learning" have a short distance between them, which means that they occurred together several times. Additionally, Fig. 6 shows that the cluster distribution of keywords belonging to both databases is almost the same (green, blue, red, and yellow clusters). The green cluster in both databases is centralized around "Second Life" and "e-learning" showing the trend of using second life as a learning environment. The blue cluster shows research trends toward communication and social interaction through the Metaverse. The red cluster represents the Metaverse technology, covering terms like virtual reality, augmented reality, avatars, and interactive computer graphics. The yellow cluster represents trends toward deep learning, educational computing, and measurement concepts.

Figure 7 shows the research methods used in Metaverse in education research. Since Metaverse is relatively an emerging topic, 41.7% of the studies did not conduct any experiment and focused on reviewing the literature and expounding theories. 20.8% of the studies used mixed methods, followed by quantitative and qualitative methods (18.8% for each). Through the analysis, it was found that the most frequently mentioned tool for collecting data was the survey, followed by the interview. This is mainly because

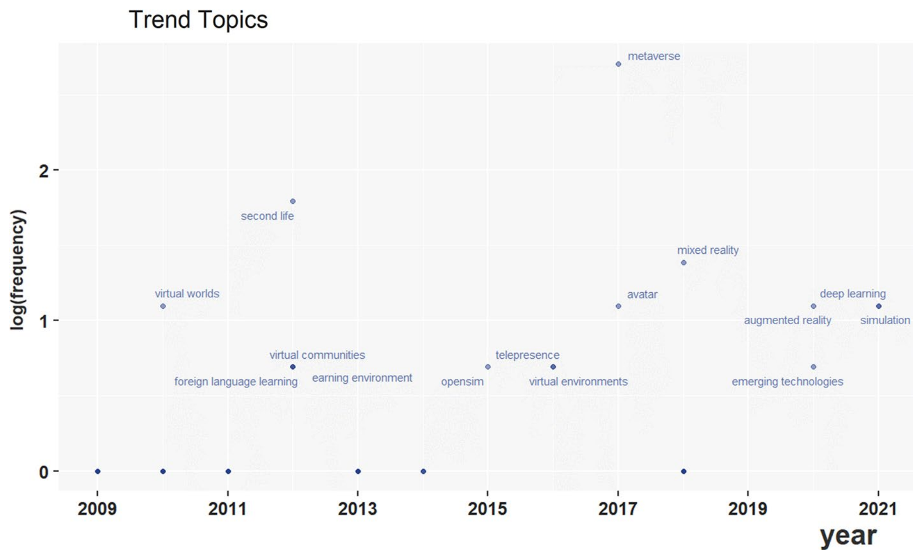


Fig. 5 Distribution of Metaverse in education by topic over the years

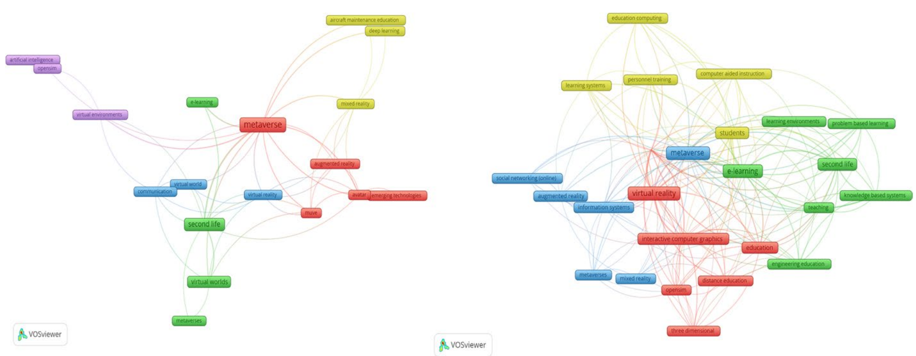


Fig. 6 Keyword clustering for the Metaverse research. Left side WoS database; Right side Scopus database

questionnaires and interviews can quickly collect data to get feedback from participants. Remarkably, we observe that a large proportion of studies did not conduct any

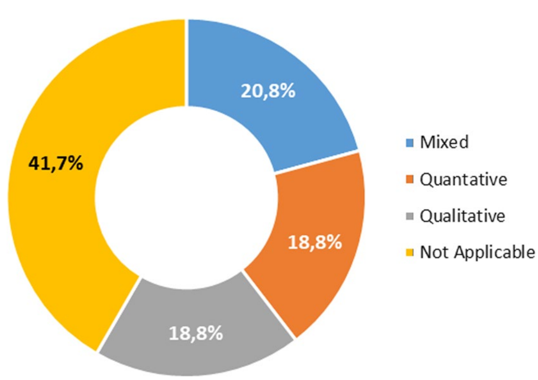


Fig. 7 Distribution of research methods in Metaverse in education studies

experiments. One of the key reasons is that the establishment of experimental setups with sensors and classroom configuration are costly, in addition to the technical barrier. Nonetheless, with the low-cost and enhanced sensing capability in digital learning environments, a classroom can turn into a sensor-driven environment, and student engagements can be captured for in-depth analysis (Wang et al., 2022). Furthermore, researchers can explore the power of big data and learning analytics to provide implicit students' assessment methods based on their log data within the Metaverse. This assessment technique could cover the limitations of the explicit techniques used (survey or interview), such as interrupting the learning process or users can easily fake their feedback. Additionally, log data can trace how students behaved and progressed within the Metaverse environments, hence gaining deeper insights about the whole learning process, unlike questionnaires or interviews.

Types of Metaverse used in education

The reviewed studies on Metaverse in education were coded according to the four Metaverse types mentioned in the 2006 Metaverse roadmap (see Fig. 1), namely Augmented Reality, Lifelogging, Virtual Worlds, and Mirror Worlds. As shown in Fig. 8, the coding was done based on two axes (x, y) separately, where each study was given two values—an x-value for (E vs I) and a y-value for (A vs S)—between − 1 and 1 each, based on the degree to which an article reflected its Metaverse technology. The y-value reflected the position of the Metaverse in the article according to the Augmentation (0–1) versus Simulation (0 to − 1), as shown in Fig. 8. A value that is closer to 1 meant that the article expressed a high level of technology exploitation and explanation in terms of

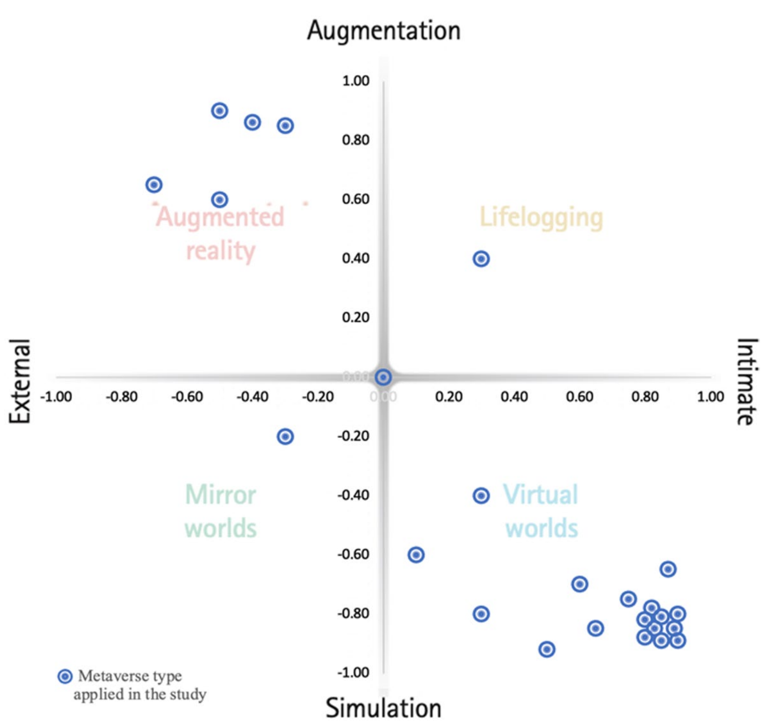


Fig. 8 Distribution of studies according to the four types of Metaverse

Augmentation, and a value that is closer to − 1 meant that the article presented a high level of technology Simulation; while a value that is closer to 0 meant that the technology was neither exploited nor explained to a high level of detail. For example, articles that presented studies conducted in Second Life (Getchell et al., 2010) or Open Simulation (Jaffurs, 2011) were given a value between 0 and − 1 on the A versus S axis, implying that they belong to virtual immersive environments that generate and manipulate models of the existing physical world. If the article presented well-informed explanations about how this immersion creates virtual interactions and experiences, the value was closer to − 1, while if the explanation was limited, the value was closer to 0. In contrast, articles that presented studies involving scanning QR codes for Augmented Reality projects (Estudante & Dietrich, 2020), or Microsoft HoloLens (Siyaev & Jo, 2021b), were given a value closer to 1.0 on the y-axis, implying that it reflects a high level of technology exploitation and explanation in applying Augmentation technologies.

The x-value reflected the position of the Metaverse in the article according to the External (0 to − 1) versus Intimate (0–1) technology. A value closer to − 1 meant that the article expressed a high level of technology exploitation and explanation with *External* environment interaction, and a value closer to 1 meant that the article presented a high level of technology application in terms of *Internal* environment interaction; while values closer to 0 meant that the technology was neither exploited nor explained to a high level of detail. For example, articles that presented studies conducted with a high level of virtual interaction (such as Barry et al., 2015) were given a value closer to 1 towards the Intimate end on the E versus I axis, implying that they belong to virtual immersive environments that focus on the behaviour of individuals within inner worlds. In contrast, studies that reflected a high level of External environment interaction (Estudante & Dietrich, 2020), were given a value that is closer to − 1 implying that the Metaverse technology focused on the users' external environment. An article with a value that is closer to 0 on the E versus I axis meant that the technology was not fully exploited nor explained to a high level of detail (Kanematsu et al., 2014). Figure 8 presents the scatter plot of the distribution of Metaverse in education studies according to the four Metaverse types. It can be seen that the majority of studies had high technological level of Simulation and Intimate interactions implying a high tendency towards using the Virtual Worlds (VW) Metaverse type.

VW is described to have a technology that reflects sophisticated computer graphics works in virtual environments through 3D technology (Kye et al., 2021). VW articles used educational elements from the VW Metaverse category such as language and translation grids as an underlying chat and communication platform in virtual reality (Farjami et al., 2011; Kanematsu et al., 2010). Overall, the educational implication of VW Metaverse types has proved to be useful since it includes virtual simulations in environments that are challenging in terms of high risks for students, such as learning about nuclear energy and safety (Kanematsu et al., 2014) or that are difficult to produce due to their high costs, such as training students in aircraft simulations (Siyaev & Jo, 2021b).

Augmented Reality (AR) is the second most frequent Metaverse category within the reviewed studies on Metaverse in education (Fig. 8). AR is described as overlaying virtual objects in the real world to make the object 3D and real (Kye et al., 2021). For instance, a page from a book in the real world can be augmented to appear as a 3D video. The reviewed studies involved scanning QR codes for AR projects to stimulate students and diffuse escape game activities for a physics lab (Estudante & Dietrich, 2020), or training students for aircraft maintenance using Microsoft HoloLens (Siyaev & Jo, 2021b). Overall, the articles didn't exploit the full educational potentials of AR Metaverse. For example, among the reviewed articles, none have offered to teach and learn invisible parts (such as the human body or the universe) by using virtual digital information presented in 3D (Kye et al., 2021).

Lifelogging and Mirror Worlds Metaverse types in education are the least frequently used among the reviewed articles. Lifelogging Metaverse is described to have one's daily life activities, thoughts, relationships to be productively shared, accumulated, and analysed through educational social media (Kye et al., 2021). One study was coded as Lifelogging Metaverse type (Siyaev & Jo, 2021a), where they integrated Augmented Reality with Intimate communication through speech interaction and recognition. This counted for a Lifelogging Metaverse type since its educational implication included reviewing and reflecting on one's professional daily communication to improve the ability to represent and implement the information in an appropriate way according to the feedback from others within the network (Kye et al., 2021). *Lifelogging* also allows students to critically and creatively explore various data on the platform to reconstruct information through collective intelligence.

Lastly, Mirror Worlds (MW) Metaverse type is described as expanding real world contexts by combining Global Positioning System (GPS) and networking technology to overcome limitations of teaching and learning due to spatial and physical restrictions (Kye et al., 2021). There was only one study (Park & Kim, 2021) that was coded as a MW Metaverse type as they used game-based immersive learning by gathering the students in a lecture room to receive a lecture by 'mirroring' a physical context into an online platform. Though the study reflected what (Kye et al., 2021) described as an "efficient expansion" system for reproducing the real world, however, the study didn't exploit the MW Metaverse to its full potentials. For example, users in MW meet and play games with physically distant people and perform meaningful tasks, but the group of students in (Park & Kim, 2021), who gathered in the lecture room, could have collectively played the game with another group of students who would, perhaps, gather in another university or another country.

Here, we provide a discussion of the findings since the majority of studies in education focused on the *Virtual Worlds* Metaverse (Kye et al., 2021), while fewer studies used the *Augmented Reality* Metaverse type; and even fewer used *Lifelogging* and *Mirror Worlds* types. Although the articles either used or explained virtual environments through implementing 3D technologies. However, according to the Metaverse roadmap, the articles in this review did not exploit nor explain the technology to a high level of complexity. For example, none of the articles reached to the level of communication and collaboration with AI characters such as the description of VW Metaverse. Furthermore, it seems that *Lifelogging* and *Mirror Worlds* types, even though were coded so, did not fully exploit the explicit technology of those two Metaverse types to a high level in educational settings as described by (Kye et al., 2021). For instance, Lifelogging can generate valuable new kinds of data, such as digital language syntax and image/video sharing by students, which can be analysed to explore new areas of integrating educational technology and psychology. Also, exploiting the technology of MW can provide a platform for Individuals with high digital competencies (Gen Z and Alpha) who are 'the future', and thus deserve attention in terms of their learning behaviour in MW Metaverse. Therefore, we suggest that future studies that consider the use of Metaverse in education exploit and explain the four types of Metaverse to a higher level of sophistication and focus on areas that have knowledge gaps such as integrating Augmentation technology with Intimate interaction (Lifelogging) or Simulation technology with External interaction (Mirror Worlds).

Educational field, level, and learning scenarios within the Metaverse

Figure 9 presents the distribution of Metaverse research in the field of education. The findings show that 53% of the Metaverse research studies were used in natural science, mathematics, and engineering, followed by general education (15%), and Arts and humanities (11%). The motivation for using Metaverse in natural science, mathematics, and engineering is because it can provide technical support for the discipline, such as providing 3D modeling computer programs for courses (Sourin, 2017), helping students to establish connections between experiments and virtual objects, and providing autonomous tutoring systems based on user interaction data mining (Pereira et al., 2015). In arts and humanities, Metaverse was frequently used for language learning as it can help people communicate with people of different languages in virtual worlds and provide new possibilities for learning foreign languages (Cruz-Lara et al., 2010). Finally, Metaverse was widely used in the field of education because combining the virtual world with physical classrooms can create new learning possibilities for collaborative, cooperative, and problem-based learning (Araya & Avila, 2018). It is worth noting that the Metaverse is less used in social science and aircraft maintenance accounting for 6% (see Fig. 9). In fact, the Metaverse can be of substantial assistance to these disciplines as well. For example, in archaeology, the Metaverse is able to provide students with individual virtual excavations, and the system helps present network communications during online e-learning experiences (Getchell et al., 2010). Therefore, future research can focus on these areas of education to provide learning experiences for more disciplines.

When investigating the education level, it was found that 62.9% of the Metaverse research was carried out in higher education (see Fig. 10). The findings show that the use of Metaverse in higher education enables interactive and immersive experiences that allow teachers and students to explore new approaches in teaching processes,

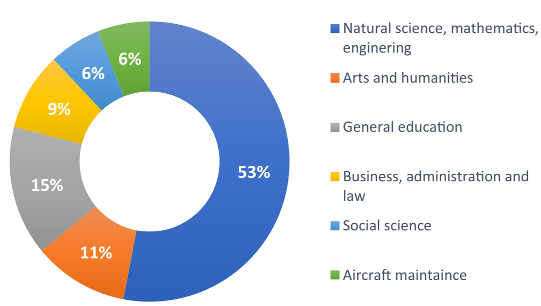


Fig. 9 Distribution of studies by education field

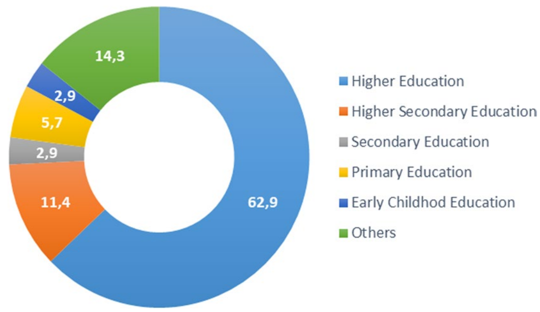


Fig. 10 Distribution of studies by education level

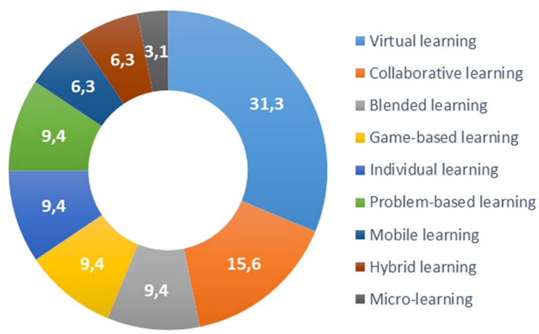


Fig. 11 Implemented learning scenarios in Metaverse in education

information and communication technologies, and emerging technologies (Díaz, 2020). It is also noteworthy that Metaverse can be significant in terms of online learning which is mainly designed through synchronous and asynchronous modes "spanning in-plane digital windows with width and height but without any depth" resulting in limitations and inefficiencies in 2D learning environments (Mystakidis et al., 2021, p. 488). Such a view implies the potential of the Metaverse in terms of lessening the limitations and inefficiencies that are inherit in traditional 2D online learning. However, limited Metaverse research focused on early childhood, primary, and secondary education. Additionally, it is found that no study focused on using the Metaverse in education with students with disabilities, calling for more research in this regard on how to develop accessible and inclusive Metaverse in education environments. The virtual freedom emerging spatially and temporally can increase the degree of inclusiveness and participation for students with disabilities and special needs.

The Metaverse can provide a set of possibilities to realize learning scenarios (Hirsh-Pasek et al., 2022). Figure 11 presents the different learning scenarios in the Metaverse. The findings show that the Metaverse is used in nine different learning scenarios in education. Most studies focused on virtual learning (31.3%, see Fig. 11), followed by collaborative learning, blended learning, game-based learning, individual learning, and problem-based learning (PBL). Tarouco et al. (2013) reported that learning in the Metaverse can provide students with an immersive learning environment, offering the possibility of collaborative learning and a high degree of interactivity. By analyzing how the Metaverse is used in different scenarios, it can help students learn more efficiently, as well as help teachers design their teaching processes in the Metaverse. This implies proposing learning and assessment strategies in the future and thinking about how it can be implemented in the immersive environments? How does the learning can be designed with cutting-edge technologies such as eye-movement technology and voice recognition technology (Hwang & Chien, 2022)?

In most learning situations, the Metaverse is used in virtual learning. This is mainly because high-performance servers are able to use the Metaverse to help students interact with various digital resources through virtual worlds (Díaz et al., 2020). Meanwhile, virtual learning scenarios are often used in conjunction with collaborative learning. This is because using the Metaverse as a social collaboration interface is where students are able to make connections in the virtual world and support guidance and feedback through an autonomous tutoring system based on data mining of user interactions (Pereira et al., 2015). For example, teachers can give students some learning topics and upload teaching resources in the Metaverse, and students can search for resources through virtual devices on the Internet (Díaz et al., 2020). Students can also interact with other peers to share academic information through internal social networks in the Metaverse, facilitating collaborative learning (Díaz et al., 2020).

In blended learning scenarios, the virtual platform created by the Metaverse is always implemented. The finding shows that it is effective to blend the lectures and guides in the virtual Metaverse with real experiments with the Metaverse and virtual systems as one of the components (Kanematsu et al., 2014). In the research of Kanematsu et al. (2014), it is noted that in STEM courses, students can conduct virtual course lectures through Metaverse (Second Life). Then, in the real classroom, the teacher can lead the students to carry out the experiment of the STEM curriculum, and in the Metaverse, the teacher conducts simultaneous instruction and teaching, so as to obtain the support of the teacher (Kanematsu et al., 2014).

Based on the virtuality and fun of the Metaverse, which is also always implemented in game-based learning. Getchell et al. (2010) showed that the Metaverse opens up new opportunities for game-based learning, which allows educators to create environments for game-based learning that are more flexible than before, allowing students to develop higher levels of control in learning scenarios, learning at a lower cost. For example, in a study by Estudante and Dietrich (2020), a digital mobile virtual reality (VR) game is proposed through the open application Metaverse. Students are guided to follow in the footsteps of physicists to solve puzzles. In this game, which includes the periodic table of elements, chemical equilibrium reactions, molar mass, and other concepts, based on game-based learning, students can master chemical knowledge points (Estudante & Dietrich, 2020). Therefore, in the context of game-based learning, the platform created by the Metaverse can serve as a tool to improve students' learning motivation and communication skills (Estudante & Dietrich, 2020).

Based on the above discussion, the problem-based learning (PBL) scenario also provides an implementation for the development of the Metaverse. In this learning context, questions and discussions are always combined, and the Metaverse emerges to provide students with a platform for problem-solving. For example, in the study of Kanematsu et al. (2012), PBL was chosen as the educational tool and the Metaverse was chosen as the classroom environment for nuclear engineering education. Teachers provide short lectures and nuclear-related problems to students in class, and students actively solve problems through Metaverse chat discussions (Kanematsu et al., 2012). The finding shows that the use of Metaverse in PBL classrooms can arouse students' attention to course content and improve classroom activity and understanding (Kanematsu et al., 2012).

Currently, few Metaverse in education studies focus on mobile learning, hybrid learning, and micro learning. In fact, through the use of the Metaverse, these learning scenarios can be attractive to students and teachers, as well as provide an ideal platform for their teaching and learning process (Díaz, 2020). The developed virtual world created by the Metaverse is able to change the traditional teaching model from static to dynamic in these different learning situations, allowing for student-centered collaboration by providing learning resources and timely assessments (Díaz, 2020).

Digital identities of students in the Metaverse and the technologies used

Digital identity formation in Metaverse environments is considered to be important in terms of improving social presence of students, that is the degree of being perceived as real (Gunawardena, 1995). Therefore, the selection or creation of avatars as well as the interaction patterns define the concept of a 'Digital Identity' as the self-image or the deep aspirations of a student *to 'be'*—which can profoundly affect and be affected by that student's online and offline learning behaviours. In this regard, there are three related of Metaverse avatars, namely: representation, presence, and immersion (Davis et al., 2009). This is thought to be important as virtual online learning is seen as a synthetic process in many cases and the lesser degree of social presence may emerge as an obstacle for interaction and communication, two essential elements of social learning. In the reviewed studies, students had the possibility to use avatars as a way to represent their digital identities within the Metaverse. Particularly, some studies provided the opportunity for students to select one avatar from the already built-in avatars (Cruz-Lara et al., 2010). Other studies provide the students the possibility to create their avatars and customize them (Díaz et al., 2020). In this context, it is seen that students create their avatars according to their own personalities (Getchell et al., 2010). As mentioned in the article by González Crespo et al. (2013), students can create digital avatars according to their own tastes and their preferred characteristics. Students can perform skills in the virtual platform, including flying, walking, purchasing different objects, and personalizing their wardrobe and appearance to interact with virtual world objects (Díaz et al., 2020). In addition to that point, students are being able to interact with other users through social chat in the virtual platform created by the Metaverse, students communicate powerfully with others through explicit or implicit references to environmental objects, gestures, poses, facial expressions (Cruz-Lara et al., 2010; Díaz et al., 2020). The digital avatar combines objects, people, and places to create a virtual three-dimensional world for the user that is basically indistinguishable from the real world (Cruz-Lara et al., 2010).

Digital avatars are also commonly found in games, and in order to increase student engagement in the classroom and rigorous academics, characters in the Metaverse often have the ability to blink (Barry et al., 2015; Díaz et al., 2020). Most studies have shown that in order to enable students to interact with other students through digital avatars, Second Life is used in the classroom to allow students to identify themselves (Barry et al., 2015; Sourin, 2017). Students can create digital avatars with different roles in the

Second Life game, such as socializers, and make more friends by interacting with other players frequently in the game (Park & Kim, 2021). Since Bailenson et al. (2002) determined the non-verbal cues associated with Metaverse avatars, we suggest developing several communication patterns of avatars including, gaze, eye direction, arm gestures, head posture, body posture, and facial expressions that enable high level of interaction and presence in the education Metaverse. Moreover, future research could examine avatar customization variables and the culture difference effects on students' decisions of their avatars. Improving the gameful experience of the educational Metaverse is crucial (Park & Kim, 2022b).

The technology and tools of the Metaverse have brought a lot of pedagogical and technical support to education, allowing students to learn immersively, thereby enhancing their motivation. In Fig. 12, technology and tools are divided into 7 categories, namely immersive, artificial intelligence (AI), game application, educational, modeling and simulation, mobile, sensors, and wearable. The direct experience given to students in the Metaverse is immersive, which not only promotes teamwork and skill development (Tarouco et al., 2013), but also engages students in classrooms in different ways (Erturk & Reynolds, 2020). In order to achieve immersion, it is necessary to combine some virtual technologies, including Virtual Reality (VR), Multi-user Virtual Environment (MUVE), Mixed Reality (MR), and Augmented Reality (AR). The technologies that serve as gateways and enable us immerse Metaverse environments also imply that the importance of multimodal immersion (Mystakidis et al., 2021). These four types of technology are currently the most common immersive interfaces in the Metaverse, which can enhance student learning in education and allow students' psychological immersion to occur, thereby enabling situational learning and transfer. The use of MR in the Metaverse is also mentioned in the study by Siyaev and Jo (2021b), showing that MR is an asset that combines physical and virtual worlds, capable of enhancing learning through deep learning voice interaction modules. Therefore, MR can mainly deal with the occurrence of voice interaction in students' learning process, allowing students to establish a deeper connection with the virtual world. In addition, VR allows virtual world servers to manage virtual environments and create avatar sharing in order to enable immersive learning for students (Cruz-Lara et al., 2010). In other words, students in the Metaverse can create their own avatars through VR, interact socially with other students, and control

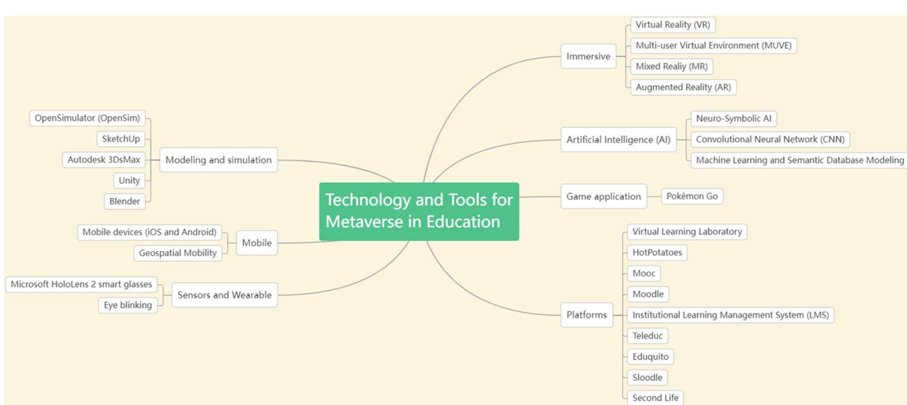


Fig. 12 Taxonomy of technology and tools used in Metaverse in education

the avatars according to the displayed environment, so as to achieve immersive effects (Cruz-Lara et al., 2010).

Figure 12 shows that game applications as another category have been widely implemented in the Metaverse to also provide immersive learning experiences. The most common game applications is Pokémon Go. It allows Pcreating fictional interactive 3D characters through real-time VR and AR technology, allowing players to "luring" pokémons in-game (Sourin, 2017).

When the Metaverse is implemented in education, it is also combined with educational platforms, allowing the immersive environments to play an important role in educational topics and making it easier to connect knowledge (Wagner et al., 2013). In Fig. 12, the Metaverse is usually combined with Second Life platform which is used in research by Rapanotti and Hall (2010) to develop an immersive virtual world platform for higher education. Second Life provides tools to create a 3D simulated avatar that combines social networking concepts with the development business network provided by Linden Labs, thereby providing students with an immersive learning environment. Students can not only create their own digital avatars in Second Life to communicate with other students virtually (Cruz-Lara et al., 2010) but also use virtual currency to purchase or build materials needed for virtual platforms (Belei et al., 2011). In the study of Getchell et al. (2010), it was also shown that Second Life, as a 3D game platform, can provide users with a real environment in the archaeology class by combining with the institutional learning management system (LMS). Besides, The Metaverse in education is combined with virtual learning laboratory, HotPotatoes, MOOC, Moodle, Institutional learning management system (LMS), Teleduc, Eduquito, Sloodle. For example, Massive Open Online Courses (MOOCs) provide students with a social network through Web 2.0 and AVAS (Wagner et al., 2013). The combination of the Metaverse and MOOC can provide subject resources to a large number of students for free, and online courses allow students to broaden their knowledge (Wagner et al., 2013). A virtual learning laboratory is usually used in natural science, mathematics, and engineering courses. Virtual Learning Laboratory (VLL) usually combines software derived from Second Life and OpenSim is widely used in the virtual world environment, providing students with a collaborative, interactive and dynamic learning environment, thereby improving students' learning motivation and learning quality (Tarouco et al. al., 2013). As a complex learning platform, Moodle can also modernize traditional content delivery, thereby enhancing collaborative learning among students (Lucas et al., 2013). For example, a virtual environment created by Moodle allows a university's e-learning platform to make presentations, link user profiles of the two platforms, and share user data (Lucas et al., 2013).

In Fig. 12, OpenSimulator (OpenSim), SketchUp, Autodesk 3DsMax, Unity, and Blender are used as modeling and simulation tools to create expert systems courses in virtual campuses to provide students with e-learning opportunities (González Crespo et al., 2013). In this category, the most common tool used by the Metaverse is OpenSim, a 3D application server originally created by Linden Labs Linden Research under the direction of Second Life (Barbulescu et al., 2011). The main feature of OpenSim is that universities can easily customise their development, design management systems, and integrate with LMS databases to create personalized content (González Crespo et al., 2013). The virtual reality platform was developed by OpenSim, with the help of Sketchup Modulator and Autodesk 3DsMax, to provide students with a visualization platform and allow student avatars to walk and interact in the virtual environment (Wagner et al., 2013).

In Fig. 12, mobile technologies are also the dominant ones in the Metaverse, including mobile devices and geospatial mobility, because of its ability to create a connection between the medium and the student, thereby enhancing authenticity in the virtual world. In a study by Estudante and Dietrich (2020), a smartphone application (iOS and Android) was used to create a virtual world augmented reality for the Metaverse. Educators in the real world can use triggers to initiate virtual world instructions on students' screens, including playing videos, calling up text and pictures, and Internet hyperlinks. In González Crespo et al. (2013), it was shown that geospatial mobility can be combined with the OpenSim system to create content tailored to the needs and methods of each institution. At the same time, geospatial mobility enables data connection and information sharing in open virtual worlds (González Crespo et al., 2013). Using Metaverse on mobile devices can enhance the learning processes when students use their avatars. Particularly, there are two possibilities with the second life Metaverse represented in (Schlemmer & Backes, 2015): (1) Mobile Grid Client Second Life and Open Simulator Messaging Client for All Android Powered Devices and (2) Pocket Metaverse iPhone and iPad Client for Second Life.

Sensors and wearable devices are one of the categories of technologies, including Microsoft HoloLens2 smart glasses and eye blinking, which enable teachers to monitor student dynamics by analyzing student behaviour (Barry et al., 2015). When students wear HoloLens 2 smart glasses, they are able to interact with content and execute commands in the virtual space (Siyaev & Jo, 2021b). The Blinking system is also a common tool in the Metaverse, mainly recording students' blinking times through specialized software (Barry et al., 2015). When students are emotionally unstable, the number of blinks in the blinking system increases, so teachers can better analyze students' responses (Barry et al., 2015).

In the artificial intelligence category, the application of neuro-symbolic AI, convolutional neural network, machine learning, and semantic database technology help students to better process learning-related data. The key concept of Metaverse lies in its complex data analysis for understanding, monitoring, regulation, and planning, and the emergence of artificial intelligence can serve as a basis for processing this data (Duan et al., 2021). Neuro-symbolic AI can combine neural networks and traditional symbolic reasoning to provide feedback on user data through automatic speech recognition metrics (Siyaev & Jo, 2021a). Neuro-symbolic AI is commonly used in aircraft maintenance training and education. For example, in aircraft maintenance courses, neuro-symbolic AI can play the role of field experts, providing technical guidance and all resources to facilitate effective training and education in aircraft maintenance (Siyaev & Jo, 2021a). For convolutional neural networks (CNN), it is often used to process audio features and the learning and classification parts for command and language recognition, thereby improving learning efficiency (Siyaev & Jo, 2021a). Machine learning and semantic database modeling are often combined with web 3.0 to allow users to access virtual worlds (González Crespo et al., 2013). Through a web-based architecture, machine learning and semantic database modeling can link with external scientific data sources, search for knowledge, and solve practical problems (González Crespo et al., 2013). Moreover, the potentials of AI in Metaverse enable new roles of intelligent Non-player Character (NPC) tutors, peers, and tutees (Hwang & Chien, 2022). Therefore, there are future research opportunities to leverage AI technologies to analyse students' behaviour and interaction patterns with their performance levels in the Metaverse and coming up with new roles.

As discussed above, several technology categories have been used in Metaverse in education to create a balanced eco-system. However, it is seen that several emerging technologies are still not implemented. For instance, blockchain could be implemented to ensure more security for the users as well as to create an anti-cheating learning system. Additionally, while cryptocurrency is frequently used in Metaverse in general, it is not the case in Metaverse in education. Internet of Things (IoT) technology could also be used to create a more immersive learning environment that merges both the physical and virtual worlds through the use of different sensors and devices. Therefore, future research could investigate how the aforementioned technologies could serve education in the Metaverse. Also, a new potential question could be raised: are the ICT-based competencies in the literature enough for students and teachers to cope with this new educational system (i.e. Metaverse in education), or new competencies are needed for better learning and teaching experiences.

On the other hand, along with all the new educational opportunities provided by technologies, users could be exposed to several risks, including identity theft, data hacks, breaches, and other financial scams and money laundering due to the decentralized blockchain-based structure that links every task to digital wallets. Furthermore, the sensors designated for understanding class participants' emotions and gestures can pose privacy threats (Bermejo Fernandez et al., 2021). Also, the augmentation of objects, as the user interaction traces in a digital classroom, can increase the risk of privacy leakages. Therefore, researchers and practitioners should pay attention to those risks when designing Metaverse in education, hence ensuring a safe learning and teaching experience.

Evolution of Metaverse in education over generations

When we grow older, we grow older together as a community. As one grows, one's parents and one's children grow older as well. The same events that affect one's own education can have a different effect on the education of different age groups in society. Although setting sharp boundaries or definitions for the different age groups is challenging, several studies offer different labels, dates, and analysis for each generation type (Moore & Frazier, 2017). The importance of clarifying generation groups lies in the fast-paced development of technology and its integration with education, especially for future generations such as Gen Alpha (Tootell et al., 2014). Therefore, the way Metaverse in education was designed and evolved over generations was also discussed. Table 1 presents the different generations highlighted in the literature.

The coding of generation types was based on the education ages of participants in the different Metaverse studies and the year in which each study was conducted. For example, a study that would involve high school students in 2020 would generally be coded

Table 1 Generation (Gen) differences

Generation Type	Baby Boomer	Gen X	Gen Y/ Millennials	Gen Z/ iGeneration	Gen Alpha
Years range	1946–1964	1965–1980	1981–1994	1995–2010*	2010–2025*
Age range as in 2022	58–76	43–57	28–42	12–27	1–12
New Technology	Television	Computers	Internet	Smart phones	Virtual Reality/ Augmented Reality
Learning style	Rote, hands-on**	Self-directed, mix traditional with technology**	Groups, lots of tests**	Groups, lots of tests, online, 'gamification'**	Online, blended, 'gamification'

*As referenced in (Jha, 2020; Nagy & Kölcsey, 2017)

**As referenced in (Moore & Frazier, 2017)

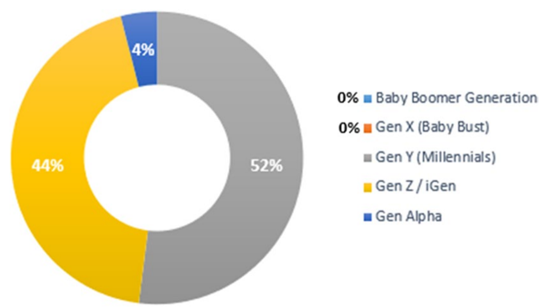


Fig. 13 Distribution of studies according to generation type

as 'Gen Z' since the participants would be around 16–24 years old in 2022. However, if the study was conducted in 2010, the participants would be coded as 'Gen Y' since they would be 26–35 years old in 2022. The distribution of Metaverse in education studies based on the generation type is presented in Fig. 13. It can be seen that 52% of the studies involved Generation Y such as (Barry et al., 2015; Getchell et al., 2010; González Crespo et al., 2013), while 44% involved Generation Z such as (Kanematsu et al., 2014; Park & Kim, 2021; Siyaev & Jo, 2021b), and 4% involved Generation Alpha such as (Mystakidis et al., 2021). Based on the obtained findings, there seems to be no studies on the earlier generations such as the Baby Boomer Generation and Gen X (Baby Bust), which makes sense, since these two generations have an age range between 43 and 76 as of 2022 (the date of writing this study), which means that almost all of them have completed their basic formal education and to many, their higher education as well. However, studies on education in the Metaverse should also consider these two generations (Baby Boomer Generation and Gen X) for their lifelong learning and how they could share their life experience to younger generations in the Metaverse. It is also seen that there was only one study that considered Gen Alpha who were born between 2010 and 2025 and have an age range between 1 and 11 years old as of 2022 (the date of writing this study). The reason why there are not many Gen Alpha participants is that this specific generation only started to appear around 2011 and did not join formal schooling until 6 years later, which is around 2017. Even after they joined formal schooling, their education was soon interrupted by the COVID-19 pandemic, which forced their education to be online. This generation is the first to be born entirely in the twenty-first century and they are mainly children of Gen Y and older members of Gen Z. This means that they were born into a society that is completely digitalized with the Internet, smartphones, and virtual reality and augmented reality technologies. If any, this generation would be the most to interact with Metaverse technologies more smoothly than the older generations, but this is just a theory that needs investigation.

Additionally, each study was coded based on the occurrences of different learning scenarios involved in using Metaverse in education according to the different generation types (see Table 2). It can be observed that Collaborative Learning is common in studies (Liu & Zhang, 2012; Rapanotti & Hall, 2010) involving Gen Y (7 times) compared to Gen Z (2 times) such as (Díaz et al., 2020; Siyaev & Jo, 2021b), while Blended/Hybrid Learning is more common for studies (Estudante & Dietrich, 2020; Kanematsu et al., 2014) involving Gen Z (6 times) compared to Gen Y (0 times). There was only one study (Mystakidis et al., 2021) that involved both Gen Z and Gen Alpha, and another study (Sourin, 2017) the involved both Gen Y and Gen Z. One more observation is that Individual Learning (Getchell et al., 2010), Problem-based Learning (Barry et al., 2015) and Project-based Learning (Tarouco et al., 2013) seem to be applied more often with Gen Y compared to Gen Z. Also, Mobile Learning (Díaz, 2020) was only applied to Gen Z Metaverse studies.

Based on the findings above, it can be understood that Gen Y is more "social" as they were born in the era of the Internet and social media. This was reflected in the Metaverse studies by relying frequently on collaborative learning (see Table 2). Gen Z also grew up in the era of the Internet and digital technologies. However, compared to Generation Y, members of Generation Z are not that digitally literate due to the age difference. This was reflected in our findings by finding that Blended/Hybrid learning

Table 2 Occurrences of learning scenarios in the studies involving education in the Metaverse for different generation types

Generation type	Learning scenario	Occurrence
Y (n = 19)	Collaborative learning	7
	Individual learning	3
	Problem-based Learning	3
	Project-based learning	2
	Game-based learning	1
	Not mentioned	3
Z (n = 17)	Blended/hybrid learning	6
	Collaborative learning	2
	Mobile learning	2
	Game-based learning	1
	Observational learning	1
	Experiential learning	1
	Problem-based learning	1
	Augmented learning	1
	Not mentioned	2
Y & Z (n = 1)	Personalized learning	1
Z & Alpha (n = 1)	Blended learning	1
Total	N/A	38

was the most frequent learning scenario for Gen Z (see Table 2). Future studies may try Collaborative Learning scenarios in studies on education in the Metaverse with younger generations such as Gen Z or Gen Alpha, and vice versa; try Blended and Online Learning scenarios with Gen Y or Gen X.

One of the important issues in the integration of Metaverse in education is the technologies and tools used for immersion. Each study was coded based on the software and tools used as a Metaverse technology in education according to the different generation types (see Table 3). It can be seen that 'Second Life' is the most common platform with 7 times used by Gen Y (Barry et al., 2015; Kanematsu et al., 2012; Tarouco et al., 2013) and 2 times used by Gen Z (Jaffurs, 2011; Kanematsu et al., 2014). The second most common technology is Virtual Reality with 4 times used by Gen Y (Liu & Zhang, 2012; Wagner et al., 2013) and 2 times used by Gen Z (Díaz, 2020; Park & Kim, 2021), and a special case where Virtual Reality (VR) and Augmented Reality (AR) were both integrated by two generations; Gen Z and Alpha (Mystakidis et al., 2021). AR is the third most common technology, and it is mainly used by Gen Z and Gen Alpha. There was only one case where Augmented Reality, along with multiple technologies, was involved with Gen Y and Z (Sourin, 2017). Furthermore, it is seen

Table 3 Occurrences of technologies and tools for immersion in the studies involving education in the Metaverse for different generation types

Generation type	Technology and tools for immersion	Occurrence
Y (n = 20)	Second life	7
	Virtual reality	4
	Learning management systems	2
	Augmented reality	1
	User interactivity	1
	Intelligent tutoring system (ITS)	1
	3D gaming platform	1
	Web 3.0	1
	Opensimulator	1
	Not mentioned	1
Z (n = 15)	Second Life	2
	Virtual reality	2
	opensimulator	2
	augmented reality	2
	Mixed reality	2
	Convolutional neural network (CNN)	1
	User interactivity	1
	Natural language processing (NLP)	1
	Moodle	1
	Neuro-symbolic AI	1
Y & Z (n = 4)	Virtual reality	1
	Augmented reality	1
	Immersive worlds	1
	Mobile network	1
Z & Alpha (n = 2)	Virtual reality	1
	Augmented reality	1
Total	N/A	41

that Artificial Intelligence, such as the application of Convolutional Neural Network (CNN) and Natural Language Processing (NLP), is more implemented with Gen Z, reflecting that the Metaverse in education environments are getting smarter from one generation to another.

There are two points to consider from this analysis; to begin with, Second Life as an immersive technological platform seems to be more common among older generations (Gen Y, see Table 3). This raises the question of how new immersive changes of Second Life would be useful to deliver education to Gen Z and Gen Alpha? Secondly, Augmented Reality seemed to be more common with Gen Z and Gen Alpha, with only one with Gen Y. This supports the first discussion point, where the later generations seem to be more involved with AR technologies rather than VR (such as Second Life). Future studies may consider three future research directions: (1) by using Second Life (or similar VR platforms) with younger generations (Gen Z and Gen Alpha) or (2) by using more Augmented Reality technologies with older generations such as Gen Y. Besides, to our understanding, most studies of Metaverse technology and tools used for immersion in education focused on students. Therefore, (3) future studies may consider teachers as research subjects to see how they can cope with these technologies.

Finally, the Metaverse in education studies were further coded based on the user-centric factors (ecosystem) and their distribution in the different generation types (see Table 4). Generally, most personal data in the digital world is "organization-centric" rather than "user-centric" where organizations have the control of gathering, management, use, and sharing of data (Moiso & Minerva, 2012). Though it is still in its early stage, one of the most common user-centric factors in the Metaverse studies in education is the Content Creation feature. It seemed that it is almost equally common with Gen Y (Getchell et al., 2010; González Crespo et al., 2013) being used 5 times, and Gen Z (Díaz et al., 2020; Estudante & Dietrich, 2020; Siyaev & Jo, 2021b) being used 6 times. Other user-centric factors are mainly involved with Gen Y. Features such as Virtual Economy (Belei et al., 2011), Social Communication (Farjami et al., 2011), or Personalize Socializing with others (Tarouco et al., 2013) are almost equally distributed among Generation Y participants. There was only one case where Virtual Economy was involved with both Gen Z and Gen Y (Sourin, 2017). There was no consideration of user-centric

Table 4 Occurrences of user-centric factors (ecosystem) in the studies involving education in the Metaverse for different generation types

Generation type	User-centric factors (ecosystem)	Occurrence
Y (n = 16)	Content creation	6
	Social communication	3
	Personalize socializing with others	2
	Virtual economy	2
	Not mentioned	3
Z (n = 11)	Content creation	5
	Personalize socializing with others	1
	Not mentioned	5
Y & Z (n = 1)	Virtual economy	1
Z & Alpha (n = 1)	Not mentioned	1
Total	N/A	29

factors towards Gen Alpha. It seemed that most studies did not consider a variety of user-centric factors with the younger generations (Gen Z and Gen Alpha). If the world of the Internet is moving towards Web 4.0 with its cryptocurrency, blockchain, and Non-Fungible Tokens (NFTs) technologies, the younger generations should be considered more in terms of their attitude towards ecosystems in the studies involving Metaverse in Education.

Impact

The impact of the Metaverse in education is positive, Liu and Zhang (2012) called the Metaverse "an important tool in the ever-increasing business scenarios in the international market". The Metaverse can play an effective role in different learning situations. For example, in the game-based classroom, the escape game created by the Metaverse using the VR platform can well facilitate mobile learning (Estudante, & Dietrich, 2020). The finding shows that students are more active in learning with games in the Metaverse than in traditional classrooms, and have a strong motivation to use smart devices to practice science (Estudante, & Dietrich, 2020). Getchell et al. (2010) evaluated the Metaverse in game-based education from various user functions and argued that the Metaverse provides a flexible platform for game-based learning and helps to create new educational environments. Metaverse teaching in virtual environments, such as Second Life, also has a positive impact, can promote multilingual communication among students and achieve better learning quality (Kanematsu et al., 2010). At the same time, in order to make the Metaverse play a greater role in the educational virtual environment, some studies have shown that the application of OpenSim, the related technology of the Metaverse implementation, has made significant progress in specific fields of engineering research, which brings greater possibilities in educational contexts (González Crespo et al., 2013).

The Metaverse also has a positive impact on students from different fields. The finding suggests that the Metaverse has greater customization, higher creativity, and lower risk to facilitate student interaction, increase motivation and engagement, and extend traditional learning by providing experiences that would otherwise be impossible (Erturk & Reynolds, 2020; Tarouco et al., 2013). These features enable the Metaverse to have a large space for implementation in the field of education. Metaverse offers aircraft maintenance students an online alternative to flying, and allows students to socialize and perform virtual aircraft maintenance in a virtual space, thereby reducing unnecessary expenses (Siyaev & Jo, 2021b). The Metaverse can also bring positive feedback to language courses, it allows the integration of the language grid system with Second Life, which enables virtual discussions between students from different countries, and the translation system will also enable students to have more concrete exchanges (Kanematsu et al., 2010). In the STEM field, the Metaverse is implemented to get students excited about avatars and virtual three-dimensional spaces that students are eager to continue learning (Barry et al., 2015). This is because the Metaverse increases the fun of learning, and the settings in Second Life increase the friendliness of teachers and the understanding of students (Barry et al., 2015). Last but not least, the Metaverse-driven classroom can blur the boundary between class participants in virtual and physical environments. As such, we can potentially consider the class participants can form a new landscape of social networks in education, which opens new research opportunities (Wang et al., 2022). However, it should be also noted that more longitudinal research is needed to truly explore the impact of the Metaverse and be ensure that most of the aforementioned positive research outputs are not result of the novelty effect of the Metaverse.

On the other hand, Table 5 presents the identified challenges associated with Metaverse in education, which can be classified into technological, pedagogical, and other types. From the technological perspective, network traffic (20.7%) had the highest percentage, followed by smartphones' interface design issue (6.9%) and the blink capture issue (6.9%). Getchell et al. (2010) pointed out that the timeliness of network communications is important, and their demands on the host server system and network traffic are more intensive. However, the current positioning of size of network communication is inaccurate and can have strange effects when evaluating students (Getchell et al., 2010). In addition, there are also studies showing that the Metaverse has a smartphone interface problem because it is a technical problem independent of the Metaverse application (Estudante & Dietrich, 2020). For example, when students study, they need to manage and install digital resources for learning through smartphones, combine technology with traditional classrooms, and create content in different formats of the Metaverse (Díaz, 2020). Reports also suggest that a smartphone's interface that is too small can limit the number of students who use it together, reducing team skills and the degree of communication with each other (Estudante & Dietrich, 2020). Furthermore, blink capture technology is also a major challenge for the implementation of the Metaverse in education. The eye-blink system is often associated with emotional responses when students discuss various issues, and using this technique in the Metaverse can improve the quality of learning (Barry et al., 2015). However, studies have shown that the recording of blinking behaviour may be compromised by problems with the student's eyes themselves, as well as creating device delays and falsely capturing blinks (Barry et al., 2015).

From the pedagogical perspective, the design of digital resources limits the development of the Metaverse, with a frequency of 13.8%, as shown in Table 5. Díaz et al. (2020) stated that the design of the Metaverse can provide students with compelling digital resources, and enable students to interact with academic information and provide interesting experiences. The digital resources implemented in the Metaverse require teachers

Table 5 Associated challenges of Metaverse in education

Category	Challenge	N	%
Technological	Network traffic	6	20,7
	Smartphone interface problem	2	6,9
	Blinks cannot be captured correctly	2	6,9
	Establishment of rules of digital coexistence	1	3,4
	Poor design	1	3,4
Pedagogical	Design the digital resources	4	13,8
	Lack of teacher competencies	2	6,9
	Lack of pedagogical structure	2	6,9
	Inflexibility of applications	2	6,9
	Difficulties with time management for learners	2	6,9
Other	Lack of quantitative analysis	2	6,9
	High design cost	1	3,4
	High practice cost	1	3,4
	Time consuming	1	3,4

to design, improve and provide to the administrators of the Metaverse servers (Díaz et al., 2020). However, due to the lack of teacher competencies and pedagogical structure in some applications (6.9% in Table 5), digital resources were not well designed (Erturk & Reynolds, 2020). It is worth noting that the Metaverse is implemented in education and there are also challenges of student time management (6.9% in Table 5). In Belei et al. (2011), it was shown that in the virtual world of the Metaverse, there are more demanding time management and a large number of technical barriers that hinder students' use. For example, when students complete a course in a virtual world, effective time management becomes extremely difficult because students do not have enough knowledge of the technology and how to apply what they read in class (Belei et al., 2011). Finally, the application of Metaverse in education will also cost a lot of time, design, and practice, which limits its development (Lucas et al., 2013).

Conclusion, implications, and future research

This study notes that despite the solid ground that it provides about the Metaverse in education, it still has some limitations that should be acknowledged. For instance, the obtained findings are limited by the databases and keywords used in this systematic review. Additionally, this current study did not review papers about the Metaverse in education which were not in English. These papers might report some interesting findings that could not be covered here. Furthermore, not too many published studies were identified from the top journals in educational technology, and this might be due to the infancy of the research topic. Therefore, this current study provides a step forward to researchers and practitioners about the potential research directions to investigate while exploring this research topic, namely Metaverse in education.

This study conducted a systematic review on Metaverse in education. The findings show that the implementation of the Metaverse can expand educational opportunities to explore environments that have historically been inaccessible due to space, time, and cost barriers, thus solving real-world problems in virtual worlds. They also reveal the research gap of lifelogging application in Metaverse education. With the rapid evolution of technology, more research efforts to deploy lifelogging applications in future classrooms with various technologies, such as AI, blockchain (a system of recording information in a way that makes it difficult or impossible to change, hack, or cheat the system), and IoT devices (i.e., the nonstandard computing devices that connect wirelessly to a network and have the ability to transmit data). Furthermore, more research should be conducted about the effect of Metaverse with students with disabilities. It is worth noting that in order for the Metaverse to be better implemented in the future, it is necessary to provide technical guidance to teachers, promote training inside and outside the classroom in synchronous and asynchronous modes, and provide students with a dynamic, engaging, and collaborative virtual platform.

On the other hand, this study would like to draw attention that Metaverse is not a new technology yet a technology that is reincarnated many times in the past two decades. As a result of the capacity increase in technology, it is here again with many blessings and curses. For instance, we have realized that many papers reviewed are lured by the possibilities emerging with the Metaverse and paid less attention to the threats it presents. Currently, its popularity is driven by the investments made by big tech companies and this necessitates approaching with caution as such initiatives may lead to many threats in the educational landscape. Though its recent history, it is still a technology in its infancy and it still has many vulnerabilities. For instance, how will users' security and privacy be ensured? What is the business model for a virtual space that generates mass volume of data? What are the moral and ethical principles for an AI powered and algorithm driven space? What are the expected social and physiological impacts of the Metaverse, a space that blurs the boundaries of physical and virtual worlds? In brief, before finding answers to some critical questions, we need to empirically investigate the blessings of the Metaverse so that we can refrain from its curses and students in the educational landscape are not lost in these immersive and imaginary spaces. Besides, from the reviewed studies, it is seen that Metaverse in education is built around emerging technologies which could be a blessing for those universities or schools with advanced infrastructure, but it could also be a curse for those that suffer from the provided infrastructure, especially in developing countries. Therefore, it is important to investigate how the Metaverse could be designed to be inclusive and accessible to all students, hence be one of the strategies to contribute to the United Nation's Sustainable Development Goals (SDGs), especially SDG4 which is about quality education.

As a final remark, this study emphasizes that Metaverse in education is still in its infancy which means that there will be many blessings and curses. Metaphorically, as in the case of the rush to the gold in the wild west, now there is a rush to the meta gold which implies that we should approach with caution due to a wide range of reasons. Again, as in the discovery of the American continent, Metaverse has many potentials which motivate many investors to colonize it, use it for profit purposes, and build new communities where they exploit them. If that is the case, we should critically ask ourselves that how will we position the teaching and learning? Besides, there are other critical questions to ask. For instance, under the influence of the EdTech companies, how will we grant agency and empower learners? How will we protect them in an algorithm driven space? Is it a free new virtual world or is it a virtual world where we are all chained with digital handcuffs? Perhaps, we should think twice before logging in the Metaverse to query if we sacrifice anything. Are we certain about that the Metaverse is a product and we are users, or we are products and the Metaverse is a user that mines and benefits from user generated data? Will it be open to only human users or will there be many *meta bots* that manipulate humans? Are we all well prepared for cyber syndromes in such virtual worlds due to being isolated from the reality in the physical world? If we are planning to use the synthetic Metaverse for teaching and learning purposes, and do we have a strategic agenda to humanize such processes? In all, there still are many critical questions to ask before we fully jump in and immerse to Metaverse because if we are tempted by the novelty effect of the *Metaverse,* all we get might be nothing but a *Metaworse.*

Abbreviations

MOOCs	Massive open online courses
AR	Augmented reality
VR	Virtual reality
MR	Mixed reality
XR	Extended reality
NLP	Natural language processing

CNN	Convolutional neural network
VW	Virtual worlds
MW	Mirror worlds
PBL	Problem-based learning
AI	Artifical intelligence
MUVE	Multi-user virtual environment
LMS	Learning management system
VLL	Virtual learning laboratory
NPC	Non-player character
IoT	Internet of Things
NFTs	Non-fungible tokens

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Declarations

Competing interests
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