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Metaverse in education: A systematic literature review

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Abstract: This article presents a summary of the prior studies on the use of the metaverse in the sector of education using a systematic literature review. The bibliometric analysis of this study is used to analyse published works in order to pinpoint the leading experts in the field, important subtopics, and potential research prospects. We also identify the most significant articles as well as patterns and clusters of related subjects. Our main findings showed that the three phrases "education," "application," and "metaverse" occurred most frequently and were connected to one another. The analysis part shows that concepts such as "challenge," "teaching," and "knowledge" have not been thoroughly researched. This research also emphasises the significance of appropriate learning settings, class layouts, the development of didactic strategies, and teacher preparation programmes. Finally, the results also present recommendations for future research in this field and provides an in-depth look at the potential uses of metaverses in education.

Subjects: International & Comparative Education; Research Methods in Education; Sociology of Education

Keywords: bibliometric; metaverse; education; artificial intelligence

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PUBLIC INTEREST STATEMENT

This study's objective is to analyse the literature on the use of the Metaverse in education. It does this through bibliometric analysis and a thorough literature review. We utilised visualisation tools to evaluate contributions to marketing research and to graphically illustrate the results of bibliometric methodologies using Elsevier's Scopus and Google Scholar databases. Academics and education policymakers may find this article helpful as it adds to the body of knowledge on the usage of the metaverse in education.

1. Introduction

The metaverse is a new idea that is receiving a lot of interest in many different disciplines, including education (Alfaisal et al., 2022). It alludes to a digital environment where users may engage with virtual things and communicate with one another in a fully immersive setting which is reachable over the internet (Durak & Cankaya, 2022). By offering engaging learning experiences that go beyond what is feasible in conventional classroom settings, the metaverse has the potential to revolutionize education (Locurcio, 2022). Virtual worlds that are very realistic and interactive may now be created for instructional purposes thanks to recent developments in virtual reality (VR) and augmented reality (AR) (Adnan et al., 2021).

Within the metaverse, students can explore scientific concepts, delve into historical events, and interact with cultural artifacts, all in ways that are not feasible in the physical world. Notably, the practicality of metaverse technology distinguishes it significantly from other VR and AR experiences (Ortega-Rodríguez, 2022). Unlike VR-focused studies that emphasize physical rendering, the metaverse is characterized by a service-oriented approach with sustainable material and social significance (Boulton et al., 2018). Furthermore, it is important to note that VR or AR is not a prerequisite for accessing the metaverse (Saputri et al., 2022). The scalable environment of the metaverse enables large-scale socialization and enhances social gatherings (Suzuki et al., 2020).

The potential benefits of integrating the metaverse into education are emerging (Fakhri et al., 2021). It can provide a more engaging and interactive learning experience, cater to individual learning styles, and reach a wider audience (Zahra et al., 2021). The metaverse also offers a safe and controlled environment for conducting experiments and simulations that would be challenging or impossible in the physical world. Several metaverse systems have been developed and continue to attract a growing number of users (Hermanto & Miftahuddin, 2021). For instance, Roblox currently boasts over 42 million active players, marking a 19% increase from 2019 (Rospigliosi, 2022). Metaverse systems are positioned to develop as virtual reality platforms becoming easier to use and more linked (Sandrone, 2022). Once virtual reality devices and peripherals include a more comfortable design appropriate for prolonged usage, the use of metaverse platforms in educational settings may become more feasible and flexible (Iwanaga et al., 2023).

However, integrating the metaverse into traditional educational systems presents challenges that need to be addressed (Hendrayati et al., 2022). Issues related to accessibility, affordability, and privacy must be carefully considered to ensure equitable access and benefits for all students (Barahona et al., 2016). Additionally, the metaverse equips teachers to design environments that support emotional learning and eliminate obstacles related to social identification and identity (Calongne et al., 2013). By providing immersive and interactive learning opportunities, promoting active communication and collaboration, and enabling both synchronous and asynchronous learning and teaching processes, the metaverse provides a flexible, diverse, scalable, and dynamic learning environment that increases student motivation (Daz et al., 2020). The metaverse has the ability to boost students' academic performance, problem-solving abilities, critical thinking skills, and general topic knowledge, resulting in higher-quality dynamic learning settings (Tarouco et al., 2013).

The goal of this research is to present a summary of the prior studies on the use of the metaverse in the sector of education using a systematic literature review. The following parts provide thorough literature analysis on the usage of the metaverse in education in order to give educators and researchers a thorough knowledge of the possible advantages and difficulties connected with this cutting-edge technology.

2. Methodology

The paper is divided into two main parts. The first section discusses the systematic literature review, while the second section covers the bibliometric analysis. To conduct the bibliometric analysis, Elsevier's Scopus database was utilized to cluster the most significant themes in the literature. The systematic review of the scientific literature was conducted following the principles outlined in Preferred Reporting Items for Systematic Reviews (PRISMA) to meet the stated purpose and provide answers to the various

research questions (Page et al., 2021). In order to enhance scientific rigor, the analytical paradigm of reported impact studies was also adhered to (Ortega-Rodríguez, 2022; Soler-Costa et al., 2021).

This study is a systematic literature review that investigates the use of Metaverse in the field of education. The existing body of literature was considered to establish a foundation for choosing the keywords. The search was conducted using the title "Metaverse" and related keywords, including "education." Our first process of searching was conducted in Elsevier's Scopus, which is known for compiling influential and scientifically significant publications, due to their impact factors (Aksnes & Sivertsen, 2019). Recommendations from specialists in the field who have focused their investigations on Scopus were also taken into account (Zhao et al., 2021). The choice of these databases was based on various reasons, including the expectation that they would contain the best integration of impact articles on educational technology, which is directly relevant to the subject of this study (Lampropoulos et al., 2022; Mystakidis et al., 2022). The inclusion and exclusion criteria, as well as the assessment of research quality and relevance, were used to determine which papers discovered in the database would be incorporated into the systematic review. Table 1 provides the reported inclusion and exclusion criteria for the scientific literature.

The literature review included full-text journal articles published in high-impact indexes, books, conference papers, and book chapters. Due to the lack of a peer-review process, technical reports, online presentations, news items, brief surveys, notes, and conference abstracts were removed (Pradana et al., 2023). Although several research works (such as articles, books, and conference papers) were found with keywords related to education and the title "Metaverse," we evaluated that some of them did not fall within the scope of this study. Therefore, the evaluation also excluded studies that did not clearly address the concept of the Metaverse or were discussed in the topics which are too distant from social science and education. Figure 1 illustrates the flowchart for the selection of studies included in the review based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al., 2021).

3. Result and discussion

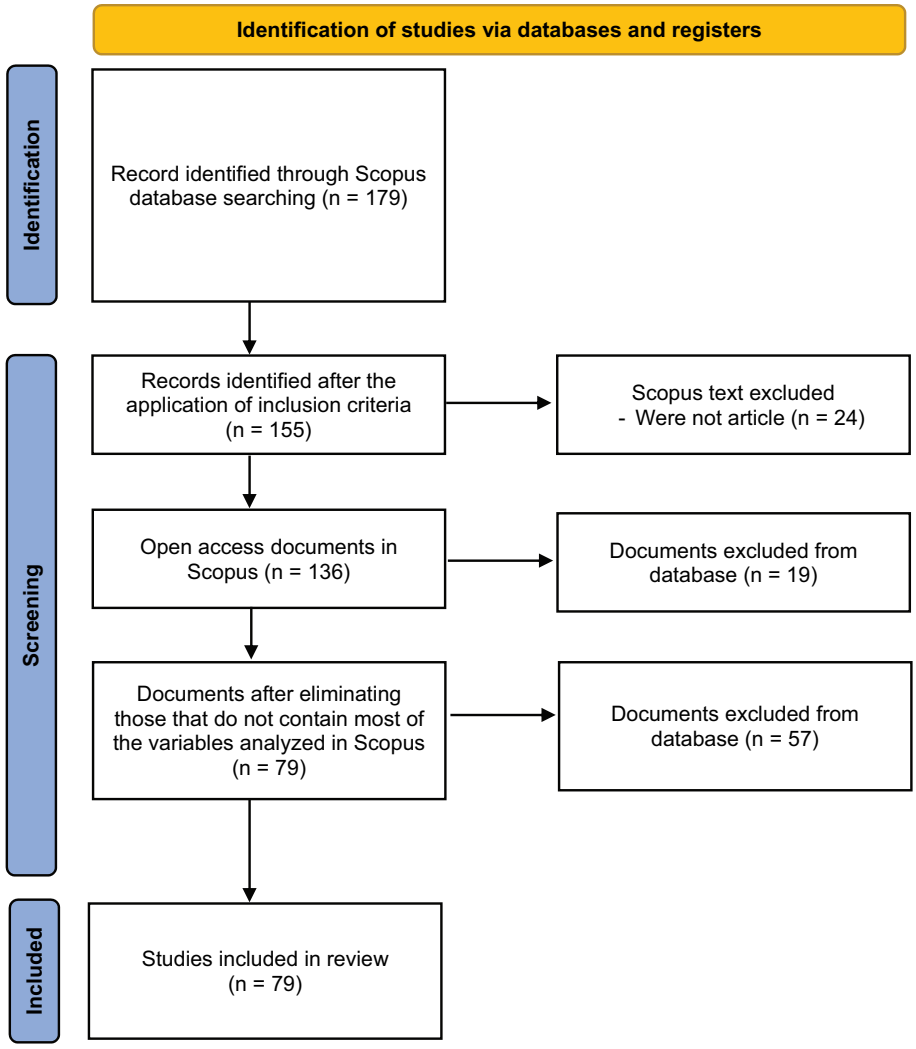
3.1. Systematic literature review

Studies containing the title "Metaverse" as well as the keyword "education" published in the Scopus database. Initially it produced a total of 179 scientific publications from the Scopus database. Following the PRISMA procedure standards for systematic review, the documentary volumes were then screened using the previously specified criteria (Figure 1). All publications regarding the use of metaverse in the sector of education were taken into consideration as inclusion criteria. 155 documents were included in the analytical sample as a consequence. Different exclusion criteria were specified, nevertheless, in order to prevent bias in the study. The final analysis was then based on 79 publications.

Table 1. Inclusion and exclusion criteria

Inclusion	Exclusion
• Academic articles, book chapters, conference papers and books • Studies with the title "Metaverse" • Studies with the word "education" • Full text studies • Public works • Studies published in English	• Whitepapers, online presentations, retraction notes, short survey, abstracts only. • Records that lacked the essence of the study's evaluated variables.

Figure 1. Research flowchart based on PRISMA.



3.1.1. Country

Currently there are two countries (South Korea: 43% and China: 29%) which can be considered as pioneers in metaverse research in education. This is the case for South Korea with six contributions (Jang et al., 2023; Lee, 2022; Lee & Hwang, 2022; Lee et al., 2022, 2022; Suh & Ahn, 2022). They are followed by countries such as China (Shu & Gu, 2023; Tlili et al., 2023; Wang & Shin, 2022; Zhou & Kim, 2022) with four contributions, followed by India (Bhavana & Vijayalakshmi, 2022; Joshi & Pramod, 2023) with two contributions, UAE (Almarzouqi et al., 2022) and USA (Beck et al., 2023) with one contribution each. The articles we analyzed are shown in Table 2.

3.1.2. Aims

The use of the metaverse in education has gained more and more attention in recent years from academics all around the world. Research studies on this subject have provided a range of aims. For instance, Lee and Hwang (2022) study the multifaceted features of instructors' preparedness to build technologically enhanced learning settings, whereas Almarzouqi et al. (2022) analyze students' perceptions of the deployment of metaverse in the UAE for medical-educational objectives. In order to address the shortcomings of current remote models of practical education, a system that incorporates virtual reality and metaverse techniques into the classroom is

Table 2. Articles about metaverse in education

Reference	Country	Type	Methodology	Sample	Main Variable	Measurement	Main Finding
(Almarzouqi et al., 2022)	Uni Emirat Arab (UEA)	Article	Multi-analytical approach that includes both survey research and statistical analysis	1858 university students	Students' perception of using the Metaverse (MS) for medical education	Survey questions	This study discovered that human and technological factors including user happiness, perceived triability, perceived observability, and perceived compatibility had a significant impact on students' perceptions of the metaverse (MS) for medical-educational reasons. The report also emphasizes how crucial it is to improve these characteristics in order to encourage more students to use MS.
(Lee & Hwang, 2022)	South Korea	Article	Primarily qualitative and descriptive in nature, with some quantitative data collected through surveys.	51 pre-service teachers from two universities in South Korea, with 27 students from University A and 24 students from University B	The ability of pre-service English teachers to create technologically enhanced learning environments is demonstrated by their experiences with instructional VR content design and metaverse platforms.	Pre-/post-surveys	According to the study, pre-service English teachers' involvement in developing instructional Virtual Reality (VR) content helped them become more technologically savvy, develop their 4Cs of digital citizenship, and see pedagogical advantages for sustainable teaching.

(*Continued*)

Table 2. (*Continued*)

Reference	Country	Type	Methodology	Sample	Main Variable	Measurement	Main Finding
(Suh & Ahn, 2022)	South Korea	Article	Data collected through surveys.	336 elementary school students	The metaverse experiences and attitudes of primary school kids, as well as variations in these variables based on grade, gender, and each metaverse factor.	Survey questions	According to the research, 95.5% of primary school pupils believed that the metaverse was directly tied to their daily lives and an average of 97.9% of kids had encountered it. Additionally, different conclusions are offered based on each participant's gender and each metaverse aspect.
(Lee et al., 2022)	South Korea	Article	A mixed-methods strategy was employed in the study, combining quantitative and qualitative techniques.	Participants who had no prior knowledge of aircraft maintenance, evenly distributed between the proposed system group and the video group.	The educational effectiveness of the proposed VR metaverse system compared to the video method, as well as the sense of presence and system usability of the proposed system.	Scores from knowledge acquisition and retention tests, a presence questionnaire, and the System Usability Scale (SUS).	The proposed VR metaverse system is more effective than the video training method for technical training, specifically in the field of aircraft maintenance. Participants who used the proposed system scored higher on both knowledge tests and retained more knowledge than those who used the video method.

(*Continued*)

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Table 2. (*Continued*)

Reference	Country	Type	Methodology	Sample	Main Variable	Measurement	Main Finding
(Zhou & Kim, 2022)	China	Article	A theoretical and analytical approach based on the examination of the trend in smart education's growth as well as the meaning and mechanism of the education metaverse from the perspective of the metaverse.	-	By creating a variety of educational situations, the metaverse-based smart education environment, which is student-centered and provides a dynamic and integrated teaching experience.	The analytic hierarchy process	Constructing many educational scenarios to create a metaverse-based smart education ecosystem that is student-centered and provides dynamic and integrated teaching experiences. The ecosystem creates a new systematic environment by balancing the ecological niches of students, instructors, society, and schools. This ecosystem serves as a theoretical foundation and point of reference for new applications of future education.
(Tlili et al., 2023)	China	Article	A mixed-method systematic review combining bibliometric and content analyses.	The papers on the use of metaverse in industry.	The use of metaverse in industry and the challenges and concerns related to its implementation.	The bibliometric analysis and content analysis of papers on the use of metaverse in industry.	According to this study, metaverse adoption in industries is still in its infancy, with the majority of research being adopted in the education and health sectors. It also revealed that there is an uneven geographic distribution of metaverse research in industries.

(*Continued*)

Table 2. (*Continued*)

Reference	Country	Type	Methodology	Sample	Main Variable	Measurement	Main Finding
(Lee, 2022)	South Korea	Article	Quantitative research method with 12-question online questionnaire	502 non-scientific students at a specific university	The non-science and engineering students who do not work with computers, their awareness of and experience with the metaverse, and their usage intentions and perceptions of the metaverse.	Online questionnaire	According to this study, non-science and engineering students who do not deal with computers had a fundamental understanding of the metaverse that was comparable to that of the general population. Students were interested in meeting friends, shopping, traveling, getting a job, attending job fairs, decorating their homes, and playing games in the metaverse. The virtual world piqued the interest of the field students the most, and they perceived communication as its major benefit since it could address the loss of face-to-face interaction caused by COVID-19.

(*Continued*)

Table 2. (*Continued*)

Reference	Country	Type	Methodology	Sample	Main Variable	Measurement	Main Finding
(I. Lee et al., 2022)	South Korea	Article	A thorough review of the state of the art of educational metaverse.	-	The use of metaverse platform in college education.	-	The use of metaverse platforms in higher education may improve active engagement, immersion, encouragement of student interaction, higher levels of customization, increased creativity, high levels of motivation and engagement, and may extend traditional learning by providing experiences that would otherwise be very challenging.
(Beck et al., 2023)	USA	Article	The evidence-based process for systematic reviews	47 literature surveys	The instructional techniques and methods applied in immersive learning settings.	A mapping survey of reviews, thematic analysis, and data synthesis.	45 techniques and 21 activities that are known to be employed in immersive learning settings. These were grouped into five major categories: “Active context”, “Collaboration”, “Engagement and Scaffolding”, “Presence”, and “Real and virtual multimedia learning.” This study identifies descriptions of real practices and tactics utilized in immersive learning environments, providing a descriptive framework for pedagogical interventions in the educational metaverse.

(*Continued*)

Table 2. (*Continued*)

Reference	Country	Type	Methodology	Sample	Main Variable	Measurement	Main Finding
(Shu & Gu, 2023)	China	Article	A combination of qualitative and quantitative research methodologies.	60 undergraduate student	The use of a smart education model enabled by the Edu-Metaverse.	Pre- and post-tests, interviews, and a questionnaire.	The study found that a smart education model enabled by the Edu-Metaverse was effective in enhancing better learning outcomes for college English students, as evidenced by higher scores in various language skills compared to traditional instruction.
(Jang et al., 2023)	South Korea	Article	Empirical investigation methodology to explore the impact of avatar customization in metaverse environments for fashion education.	38 female undergraduate students	Class mode (theoretical vs. practical), task engagement, expectancy, value, and creative self-efficacy.	A descriptive essay	That practical class mode leads to higher engagement and positive expectancy and value toward learning in the metaverse class, and creative self-efficacy moderates the impact of dedication on expectancy and value.
(Joshi & Pramod, 2023)	India	Article	A systematic mapping study		New technologies including Big Data, AI/ML, Blockchain, Cloud Computing, Quantum Computing, Extended Reality, Hyperautomation/ RPA, and Internet of Things are integrated into the CO-MATE framework.	Pre/post-COVID period to review the application of various emerging technologies	According to the study, CO-MATE, which offers anytime, anywhere, cost-effective, all-encompassing learning experiences involving advanced digital personas, ed-tech resources, self-driven and collaborative learning models, and supervised study spaces, is the future of tertiary education.

(*Continued*)

Table 2. (*Continued*)

Reference	Country	Type	Methodology	Sample	Main Variable	Measurement	Main Finding
(Wang & Shin, 2022)	China	Article	A combination of quantitative and qualitative methods.	275 individuals who completed a questionnaire survey through online and offline methods	Individualized instruction, contextualized instruction, perceived utility, perceived usability, social needs, perceived ease of use, and intended use of the metaverse education platform.	Survey questionnaire, while qualitative methods were used in the form of expert demonstrations, pre-investigations, and symposiums.	According to the study, social needs, perceived ease of use, contextualized instruction, personalized learning, and social impact all significantly increase users' willingness to use the metaverse education platform. Additionally, the study found that experience-led community-driven mode, personality-led community-driven mode, and social-led utility-driven mode are all potential guidelines for boosting usage intentions.
(Bhavana & Vijayalakshmi, 2022)	India	Article	A quantitative methodology with SEM model analysis.	The 597 participants	Using the ARCS model of Learning Motivation Dimensions, the effect of augmented reality smartphone applications on high school and college students' motivation and love for learning.	Augmented Reality smartphone app as a measurement tool.	The study found that AR technology has a bright future in education but cautioned against limiting the capacity of teachers and students to use multimedia teaching approaches.
(Yue, 2022)	China	Conference paper	A combination of quantitative and qualitative methods.	130 questionnaires collected from citizens living near educational institutions in Shenzhen	Analyzing the confidence in the potential use of the metaverse in teaching and learning in the near future	Survey questions	The study found that despite the growing interest and investment in the metaverse by technology companies worldwide, there is still a lack of understanding and faith in its implementation in education

(*Continued*)

Table 2. (*Continued*)

Reference	Country	Type	Methodology	Sample	Main Variable	Measurement	Main Finding
(Alam & Mohanty, 2022)	India	Conference paper	This study is a systematic literature review that utilizes qualitative and quantitative synthesis techniques	21 articles from the Scopus database and 36 publications from the Web of Science database	The incorporation of Metaverse in education and its impact on teaching and learning	The bibliometric analysis and content analysis of papers on the use of metaverse in industry.	The study found that the application of the Metaverse in education is still in its early stages, with the need for further research and consideration of its benefits, limitations, and ethical implications
(Sa Don et al., 2023)	Malaysia	Conference paper	Multi-stage sampling method	10 first-year students from Politeknik Premier Sultan Salahuddin Abdul Aziz Shah (PPSSAAS) in Shah Alam, Malaysia, who were selected for a focus group on flood preparedness	Flood preparedness among Malaysian higher education students, and the use of a Metaverse environment and immersive learning module is proposed to enhance their knowledge and awareness	Secondary data collection, interviews, and usability testing	The use of a metaverse-based flood preparedness module significantly enhanced Malaysian higher education students' knowledge and awareness of flood preparedness
(Raj et al., 2023)	India	Conference paper	The study is based on a structured literature review method		The integration of the metaverse into the education sector and its impact on teaching and learning		The study found that integrating the metaverse into education has the potential to revolutionize the sector by providing immersive learning experiences, improving learning outcomes, and overcoming the limitations of traditional and online education methods

suggested by Lee et al. (2022). Additionally, Suh and Ahn (2022) evaluate the metaverse's experiences and attitudes from a constructivist approach for learner-centered education.

Zhou and Kim (2022) discusses the development of a metaverse-based smart education ecosystem, and Tlili et al. (2023) presents a systematic literature review of research on the implementation of metaverse in industries. Other authors, such as Beck et al. (2023), Bhavana and Vijayalakshmi (2022), Jang et al. (2023), Joshi and Pramod (2023), Lee et al. (2022), Lee (2022), Shu and Gu (2023), Wang and Shin (2022), focus on investigating the awareness and experience of the metaverse among college students, exploring the feasibility of applying the metaverse platform in college education during the pandemic, creating a descriptive framework for pedagogical interventions, and evaluating the impact of augmented reality on classroom motivation, among other topics.

3.1.3. Methodology

Various research studies on the metaverse in education have used different methodologies, with case studies being the most commonly adopted methodology. The authors have employed quantitative (Bhavana & Vijayalakshmi, 2022), qualitative (Lee & Hwang, 2022), or mixed-method (Lee et al., 2022) approaches to analyze the impact of metaverse on students and to design virtual worlds for educational environments. Some studies used theoretical and analytical approaches (Zhou & Kim, 2022), while others used systematic reviews (Beck et al., 2023) or empirical investigation methodology (Jang et al., 2023). The methodologies used by each author can be found in the appendix of respective research papers.

3.1.4. Sample

The sample size used in the study of the educational metaverse was analyzed in 14 studies, and it was found that in 28.57% of the studies, the sample used was less than 100 participants. In only 35.71% of the studies, the sample exceeded 100 students. In addition, 35.71% of the research did not show the sample used. The specific sample size used by the authors, such as 1858 college students (Almarzouqi et al., 2022), 51 pre-service teachers (Lee & Hwang, 2022), 336 elementary school students (Suh & Ahn, 2022), and 275 individuals who completed a questionnaire survey (Wang & Shin, 2022) can found in the appendix of respective research papers.

3.1.5. Main Variable

The authors in the given list have conducted research on various aspects of the Metaverse and its impact on education. Almarzouqi et al. (2022) focuses on students' perception of using the Metaverse for medical education, while Lee and Hwang (2022) explores pre-service English teachers' readiness to design technology-enhanced learning environments through their experiences with instructional Virtual Reality (VR) content design and metaverse platform. Suh and Ahn (2022) analyzes the experiences and attitudes of elementary school students towards the Metaverse, and Zhou and Kim (2022) proposes a student-centered, smart education environment built in the Metaverse that creates multiple educational settings to give dynamic, integrated teaching experiences. The other authors in the list also examine the use of the Metaverse in different educational contexts, including industry and college education, as well as the challenges and concerns related to its implementation. The main variable in each study varies but generally includes perceptions, attitudes, experiences, effectiveness, usability, and implementation of the Metaverse for education.

3.1.6. Measurement

The authors in this text use various measurements to investigate their research questions. Almarzouqi et al. (2022), Lee (2022), Shu and Gu (2023), Suh and Ahn (2022), Tlili et al. (2023), Wang and Shin (2022) all utilized survey questionnaires to collect data. Lee and Hwang (2022) used pre- and post-tests to measure changes in participants' knowledge or skills. Lee et al. (2022) used scores from knowledge acquisition and retention tests, a presence questionnaire, and the System Usability Scale (SUS) to assess the educational effectiveness and usability of the VR metaverse system. Zhou and Kim (2022) used the analytic hierarchy process to prioritize and

evaluate the importance of various criteria. Beck et al. (2023) used a mapping survey, thematic analysis, and data synthesis to examine educational practices and strategies in immersive learning environments. Joshi and Pramod (2023) reviewed the application of various emerging technologies before and after the COVID-19 pandemic. Finally, Bhavana and Vijayalakshmi (2022) used an augmented reality smartphone app as a measurement tool to assess the impact of the app on students' learning passion and motivation.

3.1.7. Main finding

The main findings of various authors regarding the metaverse's in education. Almarzouqi et al. (2022) found that students' perception of the metaverse for medical-educational purposes is influenced by personal and technology-based characteristics. Lee and Hwang (2022) found that pre-service English teachers' experiences in creating instructional Virtual Reality (VR) content were conducive to capacitating their technological readiness and perceived pedagogical benefits. Suh and Ahn (2022) found that 97.9% of elementary school students had experiences with the metaverse and considered it closely related to their daily life. Other authors found that the metaverse enhances active participation, immersion, promotes student interaction and customization, and provides immersive learning experiences. However, Tlili et al. (2023) suggests that metaverse adoption in industries is still in its infancy, and Bhavana and Vijayalakshmi (2022) suggest against limiting teachers and students' multimedia teaching approaches.

3.2. Bibliometric analysis

This study examines 79 articles related to metaverse education, this study limits the years the articles were published with the last 10 years. However, in 2021, articles regarding metaverse education began to appear with a total of two articles. 2022 was the year with the most publications, with a total of 48 articles related to metaverse education. However, in 2023 the number of articles will decrease until there are only 29 articles. Our data is still provisional because 2023 will not be completed until December 2023, so it is still possible to add and add to the collection of papers in this study (Figure 2).

In this study, a comprehensive investigation of metaverse in education was conducted, employing data analysis techniques focused on citations and co-occurrence. The analysis of citations revealed highly cited articles and influential authors, providing insights into the scholarly impact of research in the field. The co-occurrence analysis uncovered patterns and clusters of related concepts, revealing prevalent themes and interconnectedness within the metaverse domain. These findings contribute to a deeper understanding of metaverse in education scholarly landscape, highlighting influential research and prominent topics, and providing a foundation for further exploration in the field.

3.2.1. Citation

The analysis was used to determine which articles had the greatest influence on metaverse in education. Table 3 provides further detail on the top cited on the topic of metaverse.

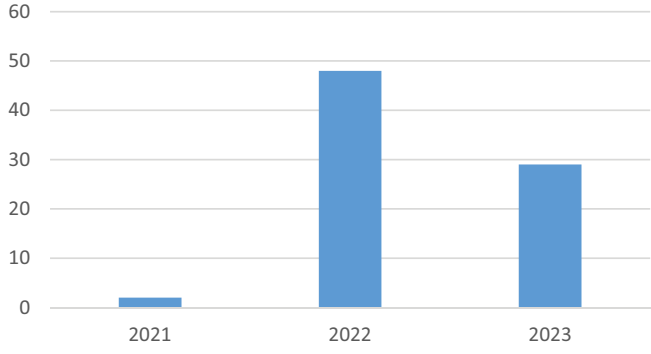

Figure 2. Number of Paper.

Table 3. Top cited articles

Citation	Title	Author	Year	C/Y	Type	Publication
53	Prediction of User's Intention to Use Metaverse System in Medical Education: A Hybrid SEM-ML Learning Approach	Almarzouqi et al.	2022	53.00	Conference Paper	IEEE Access
36	Utilizing the Metaverse for Learner-Centered Constructivist Education in the Post-Pandemic Era: An Analysis of Elementary School Students	Suh & Ahn	2022	36.00	Article	Journal of Intelligence
32	Technology-Enhanced Education through VR-Making and Metaverse-Linking to Foster Teacher Readiness and Sustainable Learning	Lee & Hwang	2022	32.00	Article	Sustainability
31	Virtual Reality Metaverse System Supplementing Remote Education Methods: Based on Aircraft Maintenance Simulation	Lee et al.	2022	31.00	Article	Applied Sciences

Table 3 provided above presents the highest citation ratings. As of 2023, the article by Almarzouqi et al. from 2022 holds the top position with 53 citations, published in the IEEE Access. The article "Prediction of User's Intention to Use Metaverse System in Medical Education: A Hybrid SEM-ML Learning Approach" by Almarzouqi et al. (2022) aims to assess how students see the use of metaverse for medical and educational reasons in the United Arab Emirates (UAE).

There is a slight concern on the quality of publication when we fully rely on the results from Elsevier's Scopus. Some articles were published under Multidisciplinary Digital Publishing Institute (MDPI), a publisher whose credibility was doubted in the research by Oviedo-García (2021a, 2021b). However, the claim of that research was then soon commented by the Oxford University Press as published: "the original version of this article has been retracted and a revised version has been published as a replacement, addressing concerns about conclusions drawn in the article."

A short while thereafter, a revised version of the article with revisions was released. A significant flaw in the earlier research was also highlighted by Oviedo-García (2023), who only looked at the review activities of MDPI-journals during a two-year period, from 2018 to 2019, and the information that was accessible in January 2020. Referring to such concern and clarification, as well as the fact that they are featured in the Scopus database, two articles from MDPI which we found as our search results, "Technology-Enhanced Education through VR-Making and Metaverse-Linking to Foster Teacher Readiness and Sustainable Learning" (published in MDPI's Sustainability in 2022) and "Virtual Reality Metaverse System Supplementing Remote Education Methods: Based on Aircraft Maintenance Simulation" (published in MDPI's Applied Science in 2022), as well as other publications by MDPI are kept in the inclusion.

Before continuing with the visualisations, we discover the significance of conducting a second search on a different database to detect articles we did not find on Elsevier's Scopus database. Unfortunately, our resources were limited, and our institutions did not have access to other databases such as Web of Science or PubMed. Therefore, we conducted our second round of literature research using the Google Scholar database. Bibliometric analysis on Google Scholar database complementing Elsevier's Scopus were conducted in several earlier research, including Ahmad et al. (2020) and Beovich et al. (2021).

Some articles from the Scopus database which we found in the first search reappeared in our second search. However, Table 4 only lists some more linked publications that were newly discovered and not identified during our initial search. To avoid unnecessary documents, the second search also removed technical reports, online presentations, news items, brief surveys, retraction notes, and conference abstracts while including full-text journal articles published in high-impact indexes, books, conference papers, and book chapters (Pradana et al., 2023).

3.2.2. Co-accuracy

Afterwards, we visualized the data using a co-occurrence analysis kind of term and retrieved 19 keywords using the full counting approach with a minimum of one co-occurrence. The co-occurrence analysis of keywords (Gaviria-Marin et al., 2018) is used to show the frequency of terms used in publications. The result can be seen in Figure 3's co-occurrence data presentation for terms.

Figure 3 shows a diagram illustrating the frequency of regularly used phrases, with the size of the circles representing the frequency. The grouping and mapping of research subjects related to the metaverse and education may be shown in Figure 3. A distinct color designates each group, signifying their affinity and relatedness to one another. The density of the elements decreases with increasing distance from the object of interest and increases with increasing number of neighboring elements, as described by Pradana et al. (2023). The co-occurrence analysis of the terms shown in Figure 3 indicates that the phrases "metaverse," "education," and "application" appear most frequently.

Table 4. Articles about metaverse in education based on Google Scholar search

Title	Author	Year	Type	Publication
A systematic literature review of the acceptability of the use of Metaverse in education over 16 years	Chua & Yu	2023	Article	Journal of Computers in Education
Metaverse applications in education: a systematic review and a cost-benefit analysis	Camilleri	2023	Article	Interactive Technology and Smart Education
Development of a framework for metaverse in education: A systematic literature review approach	Roy et al.	2023	Conference Paper	IEEE Access
Metaverse for education–Virtual or real?. In Frontiers in Education	Hussain	2023	Article	Frontiers in Education
Metaverse and Virtual Environment to Improve Attention Deficit Hyperactivity Disorder (ADHD) Students' Learning	Mohamed et al.	2023	Conference Paper	In International Conference on Intelligent Tutoring Systems
Metaverse in education: Vision, opportunities, and challenges	Lin et al.	2022	Conference Paper	IEEE International Conference on Big Data
Use of Metaverse in Education	Inceoglu & Ciloglugil	2022	Conference Paper	International conference on computational science and its applications
Analyzing education based on metaverse technology	Mustafa	2022	Article	Technium Social Science
Exploring the application scenarios and issues facing Metaverse technology in education	Chen	2022	Article	Interactive Learning Environments
Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective	Hwang & Chen	2022	Article	Computers and Education: Artificial Intelligence

(*Continued*)

Table 4. (*Continued*)

Title	Author	Year	Type	Publication
The metaverse in education: Definition, framework, features, potential applications, challenges, and future research topics	Zhang et al.	2022	Article	Frontiers in Psychology
Dental education in the metaverse	Locurcio	2022	Article	British Dental Jour nal
Metaverse system adoption in education: a systematic literature review	Alfaisal et al.	2022	Article	Journal of Computers in Education
Exploring the application scenarios and issues facing Metaverse technology in education	Chen	2022	Article	Interactive Learning Environments
The importance of the application of the metaverse in education	Contreras et al.	2022	Article	Modern Applied Science
Medical education in the metaverse	Sandrone	2022	Article	Nature Medicine
Who really needs a Metaverse in anatomy education? A review with preliminary survey results	Iwanaga et al.	2022	Article	Clinical Anatomy

In addition to network analysis, we also present overlay analysis and density visualization. Overlay visualization provides insight into the research history by showing the relationship between topics and the year of research. Figure 4 indicates that research on metaverse education was mainly conducted before 2023 and has since decreased.

Density visualization, on the other hand, shows the emphasis on the research group and can be used to identify areas that are still being explored. There are two types of density visualization: item density and cluster density. The former is represented by a color spectrum ranging from yellow to blue, with yellow indicating a more detailed discussion of the topic and blue indicating less. The latter is similar to item density, but the point of the visualization is colored to represent a group.

Figure 5 in the study provides a visualization that presents information about the number of closely related nodes and the density of co-occurring keywords. The concept of node density in this visualization is based on the work of Aribowo (2019). In this visualization, the yellow nodes represent frequently appearing terms, and the saturation level of these nodes indicates the prevalence of these terms within the research. Specifically, the keywords “Metaverse” and “Education” are depicted as yellow nodes, suggesting that they have been extensively researched and are prominent focuses within the field of study. This indicates that the topic of Metaverse Education has garnered significant attention and has been the subject of numerous studies.

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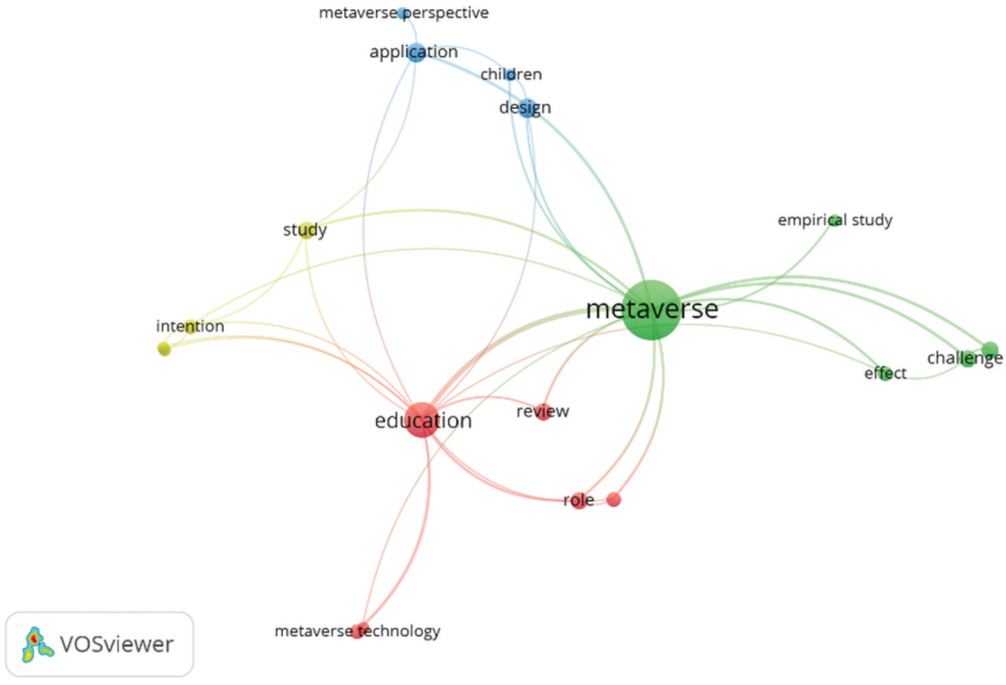

Figure 3. Co-occurrence (keywords).

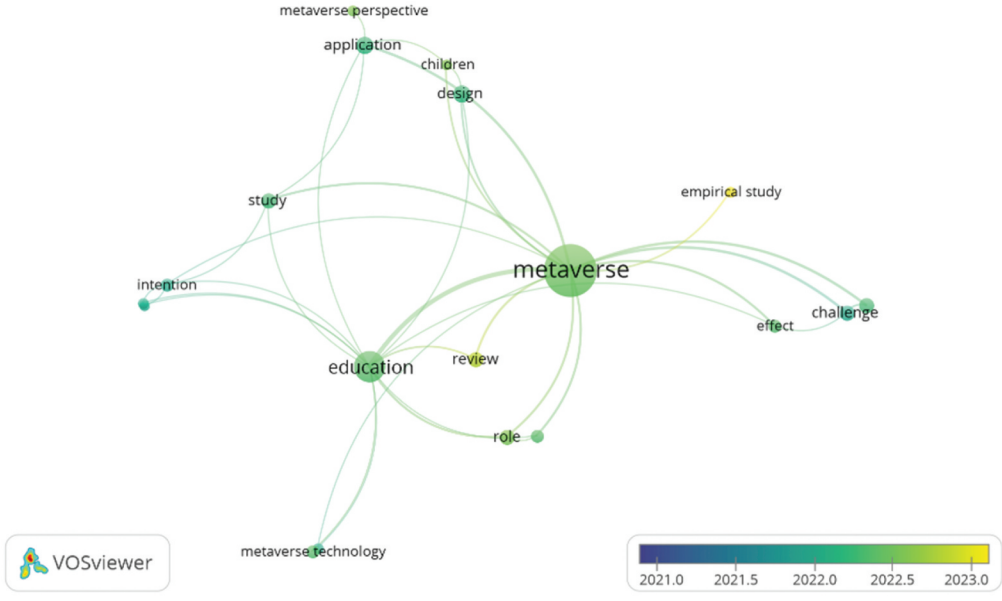

Figure 4. Overlay visualization co-occurrence (keywords).

Conversely, the green nodes, such as "role," "effect," and "design," represent topics that have not received as much extensive study within the literature on Metaverse Education. These green nodes highlight areas that have relatively lower research prevalence or attention compared to the yellow nodes. Specifically, the topics related to the roles, effects, and design considerations in the context of Metaverse Education have not been extensively explored or studied within the existing body of research.

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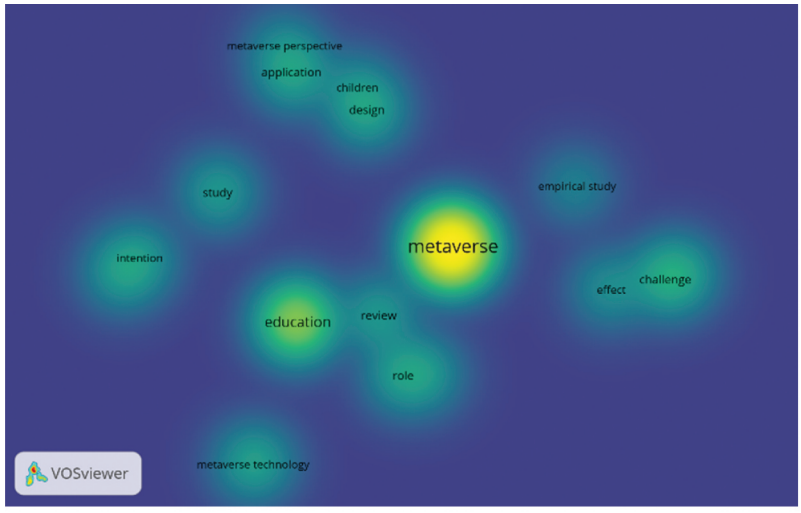
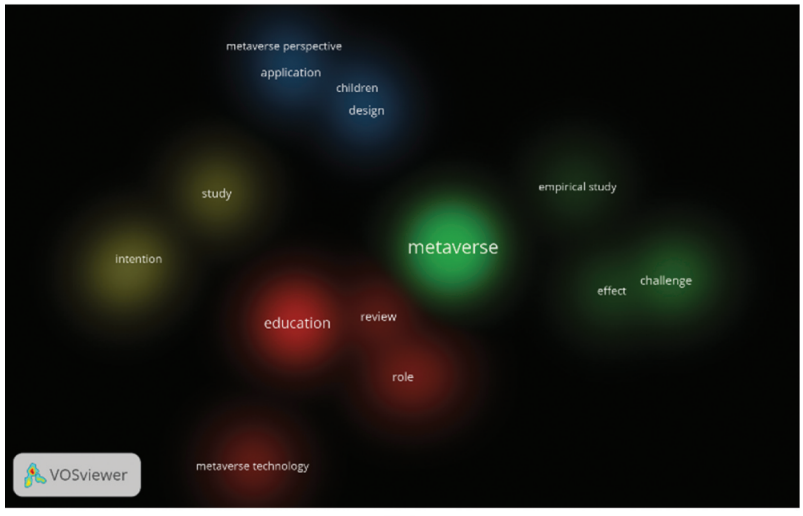
Figure 5. (a) item density; (b) cluster density.



(a)



(b)

The metaverse, with its immersive and interactive nature, holds great potential for revolutionizing education and informing more effective teaching strategies. By leveraging metaverse technology, educators can create engaging and innovative learning experiences that cater to different learning styles and preferences (Ho, 2022). The practices of metaverse offers a solution by providing opportunities for hands-on interaction and reducing distractions (Troja et al., 2023). One of the key benefits of the metaverse in education lies in its ability to support the development of relevant curricula. Educators can utilize the metaverse to design virtual learning environments and create didactic content that aligns with different curricular subjects. This opens up new possibilities for experiential learning, simulations, and virtual field trips, allowing students to explore concepts in a more immersive and engaging manner (López-Belmonte et al., 2023).

In order to fully harness the potential of the metaverse in education, attention must be given to the roles, effects, and design considerations. Educators need to consider their role in facilitating meaningful learning experiences within the metaverse, fostering collaboration and active participation among students. They can explore various teaching strategies and adapt them to the virtual environment, taking advantage of the metaverse's interactive features and multimedia capabilities

(Ho, 2022). Furthermore, the effects of metaverse integration in education need to be examined. Research should focus on evaluating the impact of metaverse-based learning on student engagement, motivation, and learning outcomes. This will provide valuable insights into the effectiveness of metaverse-enabled teaching strategies and inform pedagogical practices (Ho, 2022).

Design is another crucial aspect when incorporating the metaverse into education. Proper class and learning environment design tailored to students' needs is essential for creating effective learning experiences. Attention must be given to accessibility, usability, and the creation of inclusive virtual spaces that cater to diverse learners (Cheong & Lee, 2022). Additionally, considerations of AI ethics and digital citizenship education are necessary to ensure responsible and ethical use of the metaverse (Cheong & Lee, 2022). As we continue to explore and develop the metaverse's potential in education, there is a need for specific didactic methodologies and competence training plans to support educators in creating and utilizing virtual classrooms effectively. By embracing the metaverse, education can be transformed, promoting inclusive learning environments, improving attention to diversity, and enhancing the overall teaching and learning process (López-Belmonte et al., 2023; Peña Arcila, 2020).

4. Conclusion

The idea of the metaverse has the potential to significantly change education by offering a dynamic, varied, and adaptable learning environment that goes beyond the confines of the conventional classroom. Integrating the metaverse into education provides many benefits, including a more engaging and interactive learning experience that encourages active communication, collaboration and exploration. Metaverse enables students to dive into scientific concepts, historical events, and cultural artefacts, thereby increasing in-depth understanding and critical thinking skills. In addition, the metaverse also allows for safe and controlled experiments and simulations that may be difficult or impossible in the physical world. The metaverse's scalability allows for large-scale social gatherings that increase social interaction and create a sense of community and shared experiences. By leveraging the metaverse's immersive capabilities, educators can create student-centered learning environments that enhance motivation, problem-solving skills, and overall academic performance.

However, the integration of the metaverse into traditional education systems also poses challenges that need to be addressed. Future studies should focus on issues of accessibility, affordability, and privacy must be carefully considered to ensure equitable access and benefits for all students. While virtual reality (VR) and augmented reality (AR) technologies continue to evolve, ensuring a comfortable and easy-to-use experience for extended use is key to their widespread adoption. In addition, careful pedagogical design and appropriate implementation strategies are required to optimize the metaverse's full potential in effective learning and teaching. By addressing these challenges, metaverse can revolutionize education by offering innovative and effective teaching methods that equip students with the skills needed in the 21st century.

We realise that our research has substantial limitations. Due to our lack of access to other databases, we only explored Elsevier's Scopus database complemented by a search in Google Scholar to add depth on the result. The phases thus might not accurately reflect the quality of articles. Future research can examine additional databases like Web of Science, PubMed, or DOAJ, especially bibliometric studies. A deeper investigation of the usage of the metaverse in education may be possible using several databases' larger results and interpretations.

Future research can be focused on several aspects. First, further research can be conducted to explore the use of metaverse in special education contexts, such as medical education, arts education, or special education. This will provide deeper insight into the potential and effectiveness of the metaverse in these domains. In addition, longitudinal studies involving long-term observations of the use of the metaverse in learning can provide insight into the long-term impact on academic achievement, learning motivation, and student engagement. Furthermore, research can be focused on developing innovative pedagogies and learning models that are appropriate to the

use of the metaverse in learning. This approach will assist educators in designing effective learning experiences and maximizing the benefits of the metaverse. To guarantee that all students can benefit equally from accessing the metaverse, research must also be done to address difficulties with accessibility and pricing. Overall, the use of the metaverse in education has enormous potential to improve learning and produce more dynamic and interesting teaching and learning situations. However, challenges and aspects that need attention must also be addressed carefully to ensure fair access, user convenience, and effective pedagogical implementation. By continuing to develop research and improve educational practices related to the metaverse, education can move forward towards learning that is more innovative and adaptive to the demands of the 21st century.

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