Metaverse in Education: a Bibliometric Study

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Abstract

The term "metaverse" first appeared in Neal Stephenson's 1992 science fiction novel Snow Crash in which he defined it as a virtual environment shared over the Internet. Since the publication of that work, technological advances have allowed the creation of several metaverses for popular use—virtual world platforms such as Second Life, IMVU, VRchat, Sansar, Roblox, The Sims and Active Worlds, in addition to venturing into other fields such as education, for example, in which its use is prioritized to develop learning environments that allow students to function safely. and personalized in parallel realities. Through a bibliometric analysis of 130 documents, this article aims to review studies on the metaverse and its inclusion in education. The findings include a summary of the most important scientific articles and journals in the subject area, as well as the most prolific and prominent authors, organizations and nations. Additionally, a keyword co-occurrence analysis was made that helps reveal the main research clusters and their subtopics. The study offers a comprehensive overview of the expected impacts of the metaverse on education.

Keywords
bibliometric indicators, instruction, education, metaverse, experiential learning.

1. Introduction

First introduced in 1992, the word metaverse took a substantial boost in 2003 when the Second Life (SL) platform hit the market, which can be considered the first virtual world where a person could use an avatar to enter a parallel universe and experience simulated situations in an alternative world (George-Reyes et al., 2023b). Recently the term gained top popularity when Mark Zuckerberg presented Facebook's rebranding plan in a virtual live broadcast. At this event, the businessman showed the potential applications of the metaverse in the field of entertainment, work or learning (Zhang et al., 2022). This announcement raised attention towards this term (Damar, 2021; Chen and Zhang, 2022) generating a new beginning to eventually become a current and growing topic (Nan et al., 2023).

The metaverse is understood to be the three-dimensional space shared online where people can interact with each other using digital objects. It can also be regarded as a next-generation internet application that uses novel technologies to create a virtual living environment that can be produced and edited by users in which economic aspects, social and identity systems are integrated (López-Belmonte et al., 2022). Although its use is related to the field of video games

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and entertainment, educational technology has incorporated the use of computer software and hardware into its theories and approaches in order to help improve teaching and learning activities (Kang, 2021). Current education is in a process of transformation towards new technological paradigms (Moreno-Guerrero et al., 2021; Oliva Córdova et al., 2019; Paucar-Curasma et al., 2022). These changes motivated by the appearance of covid are prompting students to assume new roles (Pozo-Sánchez et al., 2021; López-Belmonte et al., 2023). Therefore, as technology evolves and technological challenges are resolved, it is likely that more innovative applications of metaverse will be seen in the educational field.

Current education uses virtual learning environments, virtual simulations and experiments, access to global resources, improved distance education, among others to enhance the learning experience. Each of these resources contributes to improving the interaction between students and teachers, exploring complex concepts interactively, providing access to a variety of educational and cultural resources, and enhancing the experience by creating and using more immersive and social environments (George-Reyes et al., 2023a).

Over time, and as global research on the metaverse gains strength, it will be positioned as a future educational trend, with great potential, especially because it involves technology, interaction and evolution in the way we teach and we learn (Choi and Kim, 2017; Dwivedi et al., 2022; Guo and Gao, 2022; Hwang and Chien, 2022). This contribution is manifested in the paradigm shift of traditional education and the personalized way in which learning is carried out. It can also be emphasised that it contributes to the elimination of geographical barriers and makes a variety of enriched educational resources available to users.

Bibliometric analysis is a popular and rigorous method for exploring and analyzing large volumes of scientific data. It allows us to unravel the evolutionary nuances of a specific field, while also shedding light on emerging areas in that field (Donthu et al., 2021). The objective of this study was to carry out a bibliometric review on the use of the metaverse in education, whose inclusion in the field of education, as has been described, has been favored by the context in which we live. For this reason, the need arises to delve deeper into the scientific production on this topic from a bibliometric perspective. To do this, the characteristics of the publications, authors, sources, collaborations between authors and countries and research networks were analyzed.For paragraph, use Normal. Paragraph text. Paragraph text. Paragraph text. Paragraph text. Paragraph text. Paragraph text. Paragraph text. Paragraph text.

2. Materials and methods

2.1. Design of the investigation

The bibliometric mapping technique was used in order to find research trends in the area related to the use or application of the metaverse in education. The variables analyzed were authors, publications, sources, countries, affiliations and collaborations. A bibliometric mapping is a research approach that uses quantitative techniques and bibliographic analysis to analyze and visualize scientific production in a particular field of knowledge. This method involves the collection and analysis of bibliographic data, such as journal articles, books, conferences, and other sources, with the goal of understanding patterns, trends, and relationships in the scientific literature. Unlike subjective methods, bibliometric analysis can provide an objective view of a scientific domain, as it avoids biases resulting from a selective choice of evidence (Rejeb, Rejeb, Appolloni, et al., 2023).

2.2. Search methods

Scopus database was used (Mongeon & Paul-Hus, 2016) to identify peer-reviewed articles that have addressed the metaverse and its relationship or implication in education as topics. In terms of coverage, the Scopus database was chosen since it contains 84% of the titles indexed in Web of Science (WoS), while WoS covers only 54% of Scopus titles (Rejeb et al., 2020). The following

were established as search keywords: (TITLE (metaverse AND education) OR TITLE (instruction AND metaverse) OR TITLE (metaverse AND training) OR TITLE (metaverse AND education). The following were considered as an inclusion criterion for the descriptors: only papers that include the term "metaverse." The data were exported to Microsoft Excel 365. After manual review of the documents, no duplicate articles were found.

2.3. Data extraction and analysis

After manual review of the documents, a final number of 130 articles were selected that met the study criteria. Considering the novelty of the topic, the use of filters was not necessary. Only one paper focusing on pigeon training was excluded. The rest of the results were converted to CSV (Comma Separated Values) and RIS (Research Information System) formats, to serve as analytical data (Shoaib et al., 2023). These data were used for analytical visualization regarding the international publication trend on metaverse and education.

3. Results

3.1. Initial data analysis

Table 1 shows general information about the data. Of the 130 peer-reviewed documents extracted, 105 were documents published between 2014 and August 2023. On the other hand, it was confirmed that these 105 sources have a growth rate of 61.8 %. Likewise, a high average of citations is observed, close to 7 citations per published document.

Table 1
Information on the main bibliometric data

Description	Results
Main data	
Period	2014-2023
Sources (magazines, books and others)	105
Documents	130
Annual growth rate	61.8%
Average age of the document	0.485
Average number of citations per document	6,969
References	4788

Regarding authors, a total of 438 of the 130 documents collected were obtained. Of this number, 30 are single authors. Likewise, the average per article is 4 co-authors per document, which represents 23.08% of co-authorships or international collaborations (see Table 2).

Table 2
Bibliometric information about authors

Description	Results
Authors	
Authors	438
Authors of single-author documents	30
Single-author documents	30
Co-authors per document	4
International co-authorships	23.08%

Regarding the initial data analysis, it is perceived that the type of scientific document produced on metaverse and education are original articles (62), followed by conferences. papers (37), review articles (15) and book chapters (6).

The analysis of global production per year (see Figure 1) shows a considerable increase in research production, from 1 in 2014 to 76 articles so far in 2023. This is also evident in the annual growth rate (61.8%). While the largest number of citations occurred in 2021 (44 citations).

According to the trend shown in Figure 1, the growth since 2021 has been sustained, which shows that the topic is interesting for educational researchers. It is important to highlight that the production of peer-reviewed papers increased throughout the covid pandemic, this due to the migration from face-to-face teaching to a digital context, a process that played a crucial role in various educational settings. Although there are many different types of e-learning environments, metaverse-based systems can help create safe and productive work and learning environments by using virtual reality technology and continually seeking to expand learning experiences (Devesh (Devesh & Amandeep, 2022). 2021 was known as the first year of the metaverse (C. Zhang et al., 2022). As global research on the metaverse flourishes, the topic will become a future educational trend with great potential (Shen et al., 2023; X. Zhang et al., 2022; Dwivedi et al., 2022; Guo & Gao, 2022; Park & Kim, 2022; Shin, 2022).
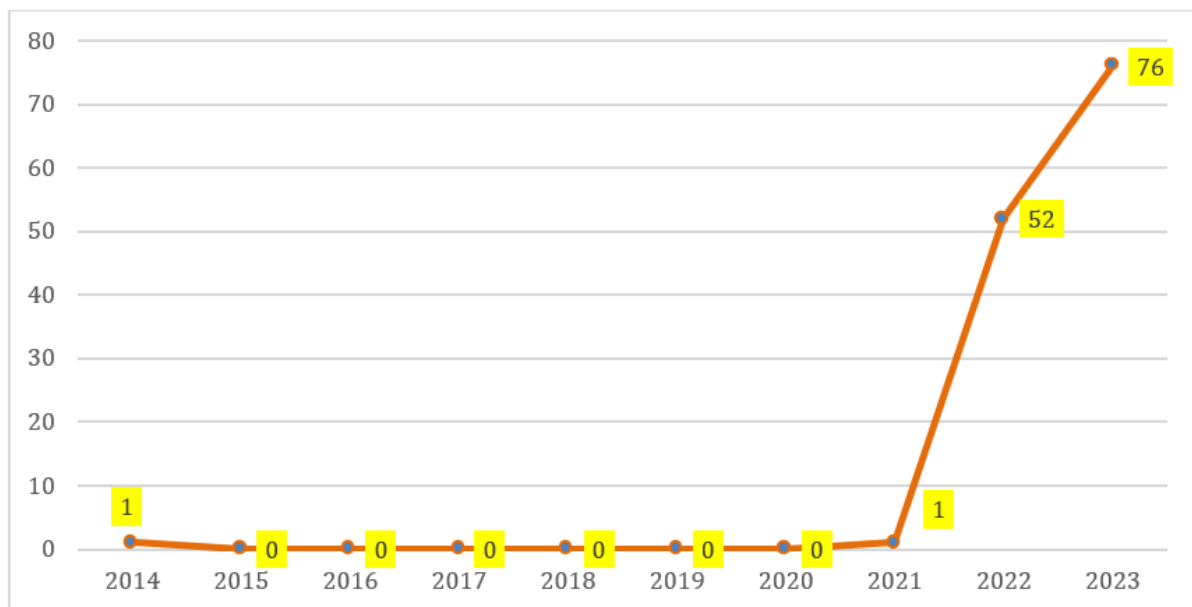

Figure 1. Annual production of research on metaverse and education.

3.2. Sources

Regarding the most important sources, the IEEE transactions on learning technologies magazine stands out (impact factor of 3.7 and citescore of 8.5) with 4 articles. In terms of impact, the journal Sustainability (Switzerland) stands out with an h index of 3 and 3 documents in total that accumulate 58 citations (see Table 3).

Table 3
Bibliometric information on the most important sources
Note: IEEE (Institute of Electrical and Electronics Engineers)

Sources	Articles	Quartile	Country	CiteScore	Publisher
IEEE transactions on learning technologies	4	Q1	USA	8.5	Institute of Electrical and Electronics Engineers Inc.

Lecture Notes in Computer Science	4	Q3	Germany	2.2	Springer Nature
Education and Information Technologies	3	Q1	USA	8.2	Springer Nature
IEEE Access	3	Q1	USA	9.0	Institute of Electrical and Electronics Engineers Inc.
IEEE Transactions on systems, man, and cybernetics: Systems	3	Q1	USA	18.9	IEEE Advancing Technology for humanity
Interactive Learning Environments	3	Q1	United Kingdom	11.0	Taylor and Francis Ltd.
Sustainability (Switzerland)	3	Q1	Switzerland	11.0	MDPI AG

4. Authors

Table 4 presents the authors with the highest production of peer-reviewed documents on the field of metaverse and education. From the list, Ahmad Aburayya from the United Arab Emirates, who is the author with the greatest production on the subject (4), the Chinese researcher Tae-Seon Lee (3), the Korean Yeonjeong Park (3) and the researcher from Singapore Salman Salloum (3) stand out. In terms of impact, Ahmad Aburayya also stands out with the indices h- (3), g- (4) and m- (1.5) with 92 citations accumulated in his 4 published articles. By author affiliation, the Korean Yonsei University College of Medicine stands out with 12 peer-reviewed documents.

Table 4
Authors with the highest production in publications

Authors	Articles	h- Index	Affiliation	Most important document
Aburayya A	4	14	City University Ajman, Ajman, United Arab Emirates	Prediction of User's Intention to Use Metaverse System in Medical Education: A Hybrid SEM-ML Learning approach
Lee T.	3	1	Yonsei University College of Medicine	Development and Application of a Metaverse-Based Social Skills Training Program for Children with Autism Spectrum Disorder to Improve Social Interaction: Protocol for a Randomized Controlled Trial
Park Y	3	13	Honam University	Educational applications of metaverse: Possibilities and limitations
Salloum S	3	8	National University of Singapore	A survey of data partitioning and sampling methods to support big data analysis
Ahamad Al-Adwan A	2	19	Al-Ahliyya Amman University	The determinants of Gen Z's metaverse adoption decisions in higher education:

5. Articles

Table 5 lists the most cited articles in the Scopus database. From the list, the 2022 study "Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective" by Gwo-Jen Hwang and Shu-Yun Chien stands out. This study proposes a clear definition of the metaverse. Possible applications and research topics of the metaverse in educational environments are also presented. Additionally, the roles of AI in the metaverse and in education are analyzed. The document has been cited 110 times, with an average of 55 citations per year and 142 visits since its publication in January 2012 in the journal Computers and Education: Artificial Intelligence from the Elsevier publishing house.

Also noteworthy is the article "Is Metaverse in education a blessing or a curse: a combined content and bibliometric analysis" by Ahmed (Tlili et al., 2022), published in the journal Smart Learning Environments of Springer Nature publishing house. This study conducts a systematic review of the literature on the metaverse in education. It then applies bibliometric and content analysis to reveal the trends, focus, and limitations of this research topic. The findings obtained present the research gap in life recording applications in the educational metaverse and analyze their evolution across the various generations. The document has 91 citations, 50.50 citations per year and 591 visits since its publication until August 2023.

Finally, the article "Prediction of User's Intention to Use Metaverse System in Medical Education: A Hybrid SEM-ML Learning Approach", published in IEEE Access, by authors Amina Almarzouqi, Ahmad Aburayya and Said Salloum. The research sought to evaluate students' perception of the application of MI in the United Arab Emirates (UAE) for medical-educational purposes. The article has 73 citations and 112 views since its publication until August 2023.

It is observed that the articles with the highest number of citations address various topics related to education and the metaverse. In them, the metaverse is presented as a kind of imagined world with immersive digital spaces that augment reality in order to generate a more interactive environment in the educational context. Studies show the importance of synchronous communication since it covers an effective number of users to share different experiences (Akour et al., 2022) (Al-Kfairy et al., 2022).

Table 5
Articles with the greatest impact in Scopus
Note: TC= Total citations.

Author, Year	Magazine	Qualification	T.C.	TC per year
Hwang, G.-J. and Chien, S.-Y., 2022	Computers and Education: Artificial Intelligence, 3, 100082.	Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective	110	55
Tlili, A., Huang, R., Shehata, B., ... Abed, M., Burgos, D., 2022	Smart Learning Environments, 9(1), 24	Is Metaverse in education a blessing or a curse: a combined content and bibliometric analysis	91	45.50
Almarzouqi, A., Aburayya, A., Salloum, SA. 2022	IEEE Access, 10, pp. 43421–43434	Prediction of User's Intention to Use Metaverse System in Medical Education: A Hybrid SEM-ML Learning Approach	73	36.50

Rospigliosi, PA, 2022	Interactive Learning Environments, 30(1), pp. 1–3	Metaverse or Simulacra? Roblox, Minecraft, Meta and the turn to virtual reality for education, socialization and work	60	30.00
Suh, W., Ahn, S.. 2022	Journal of Intelligence, 10(1), 17	Utilizing the Metaverse for Learner-Centered Constructivist Education in the Post-Pandemic Era: An Analysis of Elementary School Students	51	25.5

6. Countries

The list of countries with the greatest impact on metaverse research (see Table 6) is led by South Korea, with 254 citations in Scopus; followed by China with 200 citations and the United Kingdom with 138 citations. The country with the highest number of peer-reviewed documents is China (88), followed by South Korea (62) and India (40). Since a single document can be written by authors of different nationalities, the countries that have the highest number of collaborations are the United Arab Emirates and the United Kingdom (4 collaborations each).

Table 6
Impact by country of origin of publications in Scopus

Country	Total citations	Average citation per article
South Korea	254	13.4
China	200	6.9
United Kingdom	138	34.5
France	91	91
USA	38	5.4
Japan	37	9.2
Spain	17	3.4
Türkiye	14	2.8
Malaysia	11	11
United Arab Emirates	6	3

6.1. Co-occurrence analysis

Keyword co-occurrence analysis generated 7 clusters, 68 items, 714 links, and a total link strength of 1709. Cluster 1 (red), about metaverses, had 18 occurrences and focuses directly on metaverse and its various forms of interaction in the educational context. Cluster 2 (green), about students, had 16 occurrences and focuses on the metaverse's interaction with students. Cluster 3 (blue), about metaverse, had 13 occurrences and focuses on the different facets of the metaverse. Group 4 (yellow), about education, had 12 occurrences and referred to the relationship between covid, education and metaverse. Finally, cluster 5 (purple), above computer aided instruction, had 5 occurrences and referred to higher education (see Figure 2).

The most significant keywords were metaverse technology (9), systematic literature (7), medical education (6) and virtual reality (6), as can be seen in the world map (see Figure 3). These keywords are the basis of the studies that have been generated in the current context. The axes of interest are directly focused on the impact of the metaverse on education and on the modalities of virtual reality.
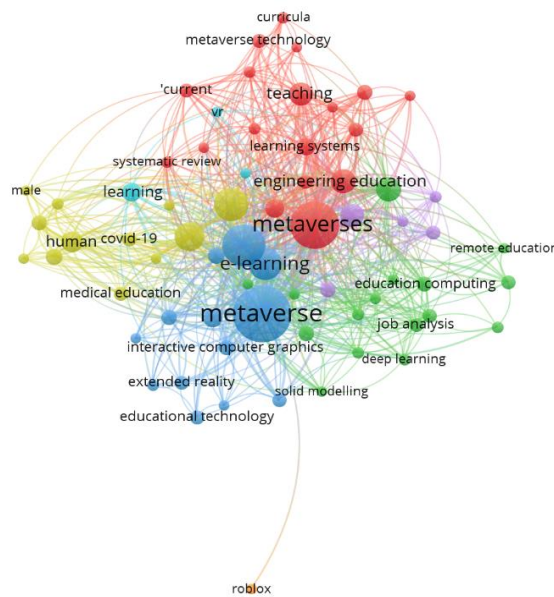
Figure 2. Network visualization analysis in Scopus

Figure 3. Keyword analysis

6.2. Thematic map

Figure 4 illustrates the thematic map with the driving themes in the upper left quadrant. These topics drive the scientific literature on the metaverse, particularly on issues related to research, applications, and future perspectives on this topic. Other important and current topics are the application of training based on the metaverse. Regarding the basic topics, education in the era of the metaverse and learning in the metaverse stand out. Among the niche topics, highly developed internally but separated from all the others, the aspects related to engineering simulators stand out, in addition to the effect on the quality of learning. On the contrary, among the emerging or declining topics, represented by underdeveloped and marginal topics in research, security in the metaverse stands out as emerging.
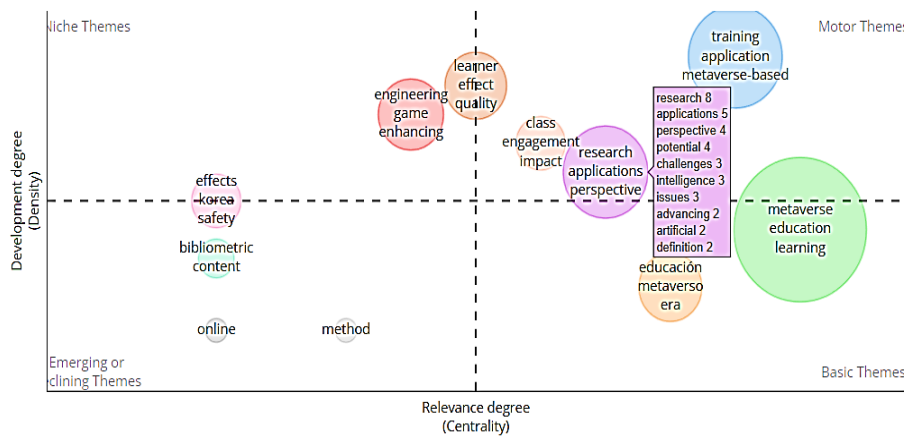
Figure 4. Thematic map (Scopus)

6.3. Factor analysis

The results of the multiple correspondence analysis (MCA), based on the Conceptual Structure Map (CSM) method, show the conceptual structure of the keywords associated with metaverse used in the articles included in this study (see Figure 5). The keywords closest to the central point have had a greater presence in recent years.

It can be seen in Figure 5 that the explained variance of dimension 1 (x-axis) reaches 75.32%, which is the highest value. On the contrary, the explained variance of dimension 2 (the least relevant located on the y-axis) is 10.62%. The red group of words in the title covers topics related to higher education and technology, which are closer to dimension 1. The results highlight the words *three-dimensional computer graphics, virtual reality, metaverses, and virtual learning*.
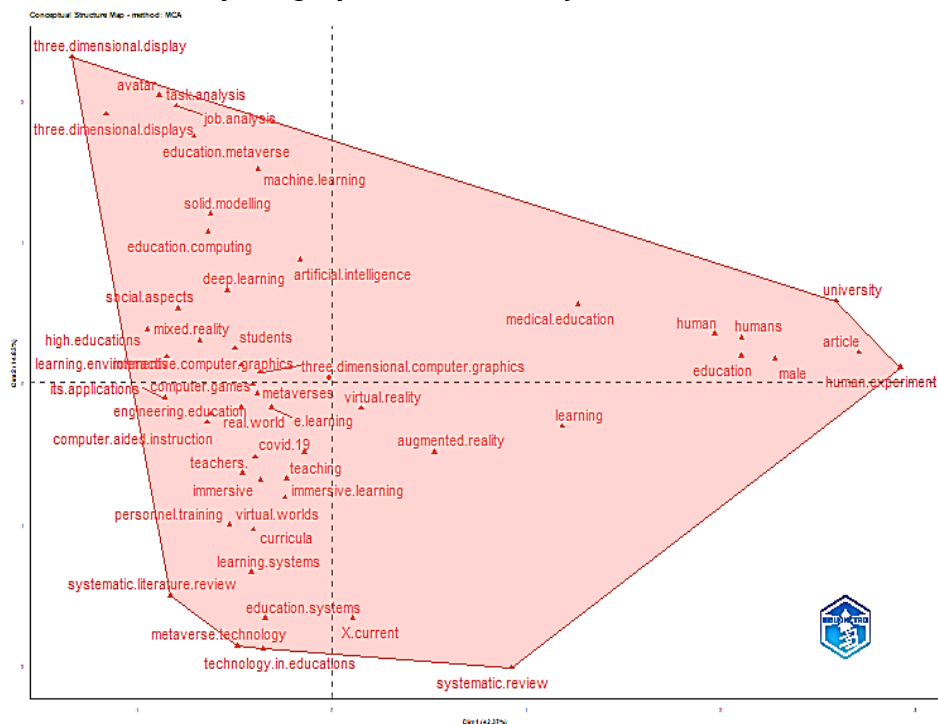

Figure 5. Factor analysis.

7. Conclusions

This study analyzed a sample of 130 documents retrieved from the Scopus database, which were published in 105 scientific journals, with 4788 references and an average citation count per

document of 7. Scientific production reaches its peak in 2023, after the covid pandemic, maintaining an annual growth rate of 61.80%. This result shows high growth from the year 2022. This growth occurred during the post-covid period, due to the popularity of virtual environments, which led to an increase in the research on metaverse (Tlili et al., 2022). This is also explained by the millionaire investments made in technologies related to the metaverse such as Meta, Google, Microsoft, NVidia, Amazon, Apple, Shopify, etc.

Regarding the most cited articles in Scopus, the 2022 study "Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective" by Gwo-Jen Hwang and Shu-Yun Chien stands out, whereas Ahmad Aburayya from the United Arab Emirates is the author with the largest number of publications on metaverse in the field of education. IEEE Transactions on learning technologies (impact factor of 3.7 and citescore of 8.5) is the source with the largest number of publications on the topic (4 articles).

On the other hand, the list of countries with the greatest impact is led by South Korea with 254 citations and 29 peer-reviewed documents. The most important affiliation is the Yonsei University College of Medicine of South Korea, results that coincide with those found by Chen and Zhang (2022). The keyword co-occurrence analysis generated seven clusters, highlighting the metaverse and its various forms of interaction in the educational context (specifically with students), its facets, covid, higher education and its relationship with the metaverse. Very similar results were those obtained by Bicen and Adedoyin (2022) who demonstrated the impact of the metaverse in remote education, medical and health education, its use to improve learning, evaluation and participation of students and teachers, as well as its impact on higher education.

The most significant author keywords were metaverse technology (9), systematic literature (7), medical education (6) and virtual reality (6)--the axes of interest being those focused on the impact of the metaverse on education and the modalities of virtual reality. This was corroborated by various investigations such as that of Chen and Zhang (2022) and that of Agac et al. (2023), who state that the use of metaverse resources in the field of medicine focuses mainly on multimodal medical information standards, fusion of medical and social data, telemedicine and online health management, and medical artificial intelligence.

In the thematic map we can observe the driving themes that drive the scientific literature on the metaverse, in particular, all issues related to research, applications, future perspectives and the validity of the application of training based on the metaverse. Chen and Zhang (2022) highlight that the metaverse offers a variety of collaborative, intelligent, immersive and synthetic environments for educational purposes. That is, metaverse technologies can establish a platform where intelligent learning environments connect the physical world with the virtual one. Regarding the basic topics, education and learning in the era of the metaverse stand out, which is corroborated by studies such as those by Tlili et al. (2022), Mustafa (2022), Hirsh-Pasek et al. (2022), Yue (2022), Almarzouqi et al. (2022) and Kaddoura and Husseiny (2023).

Regarding emerging topics, academic certification based on the metaverse stands out. Blockchain technology plays a crucial role and provides a decentralized infrastructure for the metaverse, developing strong use cases for its ecosystem (Gadekallu et al., 2022) through the quality, privacy and security of data in the metaverse. Furthermore, it provides a complete economic system that allows virtual goods to become physical objects (Jeon, 2021; Trunfio and Rossi, 2022).

In relation to the possible applications of the metaverse in education and learning, the application of metaverse-based training through immersive learning environments stands out. In addition, academics could investigate the metaverse and its various forms of interaction in the educational context, evidencing how it interacts with students from diverse geographical locations and cultures, evaluating its development and personalized interaction, but at the same time its integration into a globalized world (Rejeb et al., 2023).

From a practical perspective, the findings of this study have great importance for the different stakeholders involved in the development and implementation of metaversal technologies within educational systems. This research identified different thematic groups that offer valuable information for the education industry seeking to use the potential of the metaverse to revolutionize various sectors within education. Finally, it is necessary for professionals,

politicians and researchers to prioritize the responsible and equitable development of the metaverse, which is why the focus of this bibliometric review is based on ethical and sustainability considerations.

Despite the significant findings, this study has some limitations. Firstly, the exclusive use of the Scopus database to obtain scientific documentation may generate a selection bias, because not all published scientific literature on the metaverse and education was covered in Scopus. It is suggested that the databases be expanded to provide a more complete spectrum of the topic. Furthermore, future research can study the application of the metaverse in instruction and training in various areas. Secondly, it is likely that the 130 articles selected are not fully representative of the corpus of research on the metaverse and education, considering that the present research was specifically oriented to the metaverse and not its predecessors. Finally, while bibliometric analysis has its advantages, this methodological approach may not adequately capture the depth and complexity of this topic. Therefore, it is advisable to generate qualitative studies and systematic reviews that enrich the significance of the phenomenon and help interpret the modifications generated in the metaverse and the complexity of its development.

8. Financing

9. Data availability statement

The information included in this article is the result of the analysis carried out by the researchers. Readers or reviewers who require additional information to validate the content of the study may send their queries to the authors.

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