


A Bibliometric Analysis of the Use of the Metaverse in Education Over Three Decades

Wentao Chen, Zhejiang Yuexiu University, China

Jinyu Zhang, Zhejiang Yuexiu University, China

Zhonggen Yu, Beijing Language and Culture University, China*

 <https://orcid.org/0000-0002-3873-980X>

ABSTRACT

Since Facebook announced itself as Meta, the metaverse has been popular with educationalists. However, scanty studies have bibliographically analyzed the use of the metaverse in education. This study complements the missing link in the literature by bibliometrically analyzing the research into the use of the metaverse in education using both VOSviewer and CitNetExplorer. The study identified the top authors, organizations, countries, keywords, documents, sources, the research trends, and challenges of the metaverse used in education, together with the effects of the metaverse on learning environments, interactions, educational outcomes, and learning attitudes. This study paves a solid ground and provides a meaningful reference for future research in the use of the metaverse in education. Implications for future research were also provided.

KEYWORDS

Bibliometric Analysis, CitNetExplorer, Education, Metaverse, VOSviewer

INTRODUCTION

The concept of the metaverse has been defined in various ways since its inception in Neal Stephenson's novel (1992). The term "meta" in metaverse signifies transcendence or virtuality, while "verse" refers to a universe or world. In the context of education, the metaverse refers to a virtual reality space that can be accessed through digital technologies. It offers enhanced interactivity and immersion, allowing students to engage in learning activities and communicate synchronously with others. However, this term remains vague and encompasses diverse elements related to learning, teaching, 3D environments, and online educational technologies.

The use of the metaverse in education has rapidly evolved from games for entertainment purposes to serious games for educational purposes, providing both challenges and opportunities for teachers and learners. With the advancement of extended reality, including virtual reality, augmented reality, and mixed reality, the metaverse has gained attention as an innovative technology with potential benefits

DOI: 10.4018/IJICTE.322101

*Corresponding Author

This article published as an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>) which permits unrestricted use, distribution, and production in any medium, provided the author of the original work and original publication source are properly credited.

for education. However, its implementation requires ethical codes, interdisciplinary cooperation, and adequate training to avoid posing a significant challenge for educators and learners. Nevertheless, there has been a lack of comprehensive exploration of these issues.

While some review studies (Table 1) have explored the evolution, publication trends, possibilities, limitations, anatomy education, and healthcare system in the field of the metaverse used in education, little is known about its effects on educational outcomes, interactions, and learning attitudes in mobile, blended, and situated learning environments. Therefore, it is crucial to conduct bibliographic analysis on the use of the metaverse in terms of these variables in the field of education.

LITERATURE REVIEW

With a growing number of information technologies used in education, researchers are holding a more intense interest in the metaverse. This section aims to propose research questions by reviewing previous studies on the use of the metaverse in education.

Virtual and Real Environments

The metaverse can provide various environments to improve educational outcomes. The metaverse aims to establish a virtual platform independent of the real world via a variety of digital technologies such as virtual reality, augmented reality, deep learning, cloud computing, and big data. The metaverse can benefit teaching and learning in most disciplines, especially in the context of blended learning and teaching (Hines & Netland). The most important use of the metaverse in education is that it can provide immersive and interactive environments for teachers and learners, synchronously satisfying them in both physical and virtual environments. The metaverse can create the immersive environments where users can interact with digital avatars, enhancing the learner-centered education and enriching learners' learning experiences (Suh & Ahn, 2022). The metaverse can identify learners' emotional changes, and enhance learners' cognition, immersion, and interactivity by supporting English language learning and teaching networks (Guo & Gao, 2022).

Interactions in the Metaverse

Interactions can be enhanced due to the multiple functions of the metaverse. The metaverse and virtual environments can act as an effective digital instrument to enhance interactions in learning and teaching in a university, where both synchronous and asynchronous interactive methods can facilitate knowledge delivery and acquisition, enhanced by mobile, collaborative, or flipped pedagogical approaches (Diaz et al., 2020). The metaverse such as Second Life can be used as a platform where game-based education can be implemented (Getchell et al., 2010), improving interactions in educational practice. Interactions through the metaverse can stimulate students' interest and improve the knowledge exchange, and opinion sharing, leading to improved educational outcomes.

Table 1. A comparison between previous review studies and the current research

Publications	Highlights
Tlili et al., 2022	Evolution, publication trends, types, educational fields, and digital identity
Kye et al., 2021	Possibilities and limitations
Iwanaga et al., 2022	The metaverse in anatomy education
Bhugaonkar et al., 2022	The trend of the metaverse in the healthcare system
The current study	Bibliometric analyses

Educational Outcomes Through the Metaverse

The metaverse can improve educational outcomes in both virtual and physical environments. The rapid development of digital technologies has pushed forward the use of virtual technologies and the immersive metaverse environments in the education of Physics Mechanics among students at the Universidad Militar Nueva Granada (Jaramillo-Mujica et al., 2017). The metaverse platforms can provide learners with the skills to build virtual environments which may simulate learning experiences in the real world and overcome barriers due to the COVID-19 pandemic. The integration of virtual reality into the metaverse can complement the shortcomings of online education and produce higher educational outcomes than the video-based training method (Lee et al., 2022). The metaverse platform, VoRtex, can provide virtual environments for learners to collaborate and interact with each other, simulating the real-world learning activities and improving online learning effectiveness (Jovanovic & Milosavljevic, 2022). The metaverse, e.g. Second Life, can facilitate blended learning and enhance learning activities on different educational levels (Kanematsu et al., 2014).

Learning Attitudes Toward the Use of the Metaverse

Users tend to hold positive learning attitudes toward the metaverse used in education. The metaverse technologies can provide education, navigation, and mobile services. Mobile metaverse applications have been gaining popularity due to their convenience and accessibility (Lee et al., 2022), leading to positive learning attitudes of users. A combination of artificial intelligence with the metaverse can improve physical education, coupled with educational convenience and positive learning attitudes. The 360-degree football teaching assisted with the metaverse can improve teaching strategies and effectiveness, and facilitate the integration of artificial intelligence into football education (Li et al., 2022). The metaverse and computer games can be used in education, assisted with virtual reality and physical reality technologies (Schlemmer & Marson, 2013), leading to enhanced entertainment and positive learning attitudes toward the use of the metaverse. Virtual reality can be associated with the metaverse platforms to sustain educational outcomes, enhance learning adaptability, and cultivate positive learning attitudes (Lee & Hwang, 2022).

Until present, there have been few studies conducting a bibliographic review on and a chronological trend in the use of the metaverse in education. Researchers thus proposed the following research questions to complement the missing links in previous studies and reveal the potential challenges in the use of the metaverse in education:

RQ1: What is the chronological research trend of the use of the metaverse in education?

RQ2: What are the top ten authors, organizations, and countries in the studies on the use of the metaverse in education?

RQ3: What are the top ten keywords, documents, and sources in the studies on the use of the metaverse in education?

RQ4: What educational environments can the metaverse create?

RQ5: Can the use of the metaverse enhance interactions?

RQ6: Can the use of the metaverse improve educational outcomes?

RQ7: Can the use of the metaverse cultivate positive learning attitudes toward education?

RQ8: What are the challenges in the use of the metaverse in education?

METHODS

This study will employ techniques from online databases, VOSviewer, and CitNetExplorer to address research questions. Using specific syntactic rules, researchers will retrieve results from the Core Collection of Web of Science. Results will be visualized by bar charts displaying publication years with the largest number of results. The online database will process data with an embedded algorithm

to show yearly trends in metaverse research for educational purposes. This serves as useful reference for researchers and practitioners.

Bibliographic analysis will be conducted using CitNetExplorer and VOSviewer. Both tools cluster documents and analyze results. CitNetExplorer clusters documents based on citation networks and analyzes results on individual level, while VOSviewer analyzes clustering results on collective level. Visualization enhances analysis of clustering results. Top authors, organizations, countries, keywords, documents, and sources will be analyzed using VOSviewer. CitNetExplorer will analyze highlights of visualized literature.

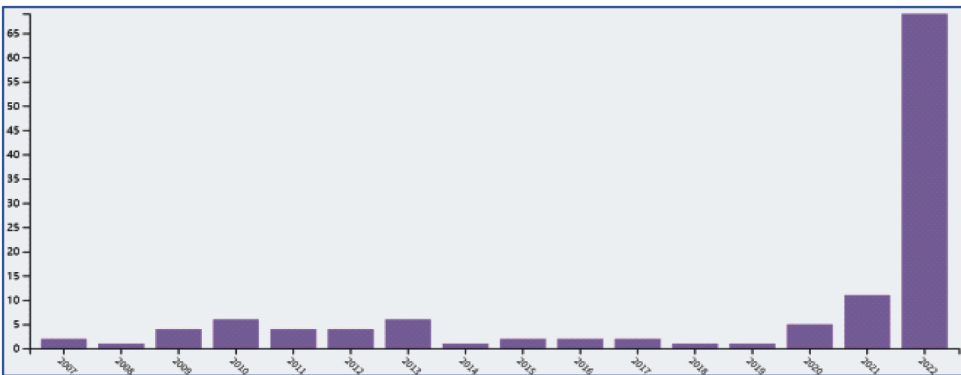
RESULTS

RQ1: What is the chronological research trend of the use of the metaverse in education?

On October 7, 2022, researchers retrieved 121 results from the Core Collection of Web of Science for “metaverse*” and “educat* OR learn* OR teach*” topics. The obtained literature comprises Highly Cited Papers (n=1), Review Article (n=11), Early Access (n=10), Open Access (n=68), and Enriched Cited References (n=39), published between 2007 and 2022. The main citation topics include Human Computer Interaction (n=18), Education & Educational Research (n=9), Remote Research & Education (n=6), Management (n=6), and Communication (n=4). The primary document types include article (n=69), proceeding paper (n=35), review article (n=11), early access (n=10), and editorial material (n=4). The leading author affiliations comprise Clarkson University (n=3), Suzuka College (n=3), Augmented Knowledge Corporation (n=2), Centre National De La Recherche Scientifique C.N.R.S. (n=2), Gifu University (n=2), Hubei Normal University (n=2), and Inha University (n=2). Figure 1 illustrates the specific years when the relevant publications were retrieved.

As depicted in Figure 1, investigations concerning the application of the metaverse in educational contexts commenced in 2007 with a limited number of studies (n=2). Subsequently, the quantity of studies remained relatively low and exhibited fluctuations until 2021 when a modest increase was observed (n=11). However, in 2022, there was a significant surge in the number of studies related to metaverse education, with a total of n=69 studies conducted until October of that year. Notably, the majority of these studies focused on topics such as Human Computer Interaction (n=13), Literary Theory (n=2), Robotics (n=2), Security Systems (n=2), Remote Research & Education (n=2), Geometrical Optics (n=2), and Social Psychology (n=2). Nevertheless, bibliometric analyses of studies on the use of the metaverse for educational purposes have been scarce. Therefore, conducting bibliometric analyses on this topic is imperative.

Figure 1. Visualization of the yearly publications in the metaverse in education



RQ2: What are the top ten authors, organizations, and countries in the studies on the use of the metaverse in education?

To provide a clear direction for researchers, identifying the top authors, organizations, and countries in the field of metaverse education based on citations is crucial. Using bibliographic data files and conducting co-authorship analysis, researchers utilized VOSviewer to create a map and generate a list of the top ten authors, organizations, and countries based on full counting (Table 2). The results revealed that certain authors and organizations have received high citation rates, indicating their significant contributions to the field and highlighting a trending research topic. These findings offer valuable references for both researchers and practitioners interested in exploring the application of the metaverse in educational contexts.

RQ3: What are the top ten keywords, documents, and sources in the studies on the use of the metaverse in education?

To provide additional references for researchers and practitioners, the present study identified the top keywords, documents, and sources based on occurrences and citations (Table 3). By examining frequently occurring keywords, researchers and practitioners can gain insights into the latest research trends and critical issues in the field. Moreover, the top documents and sources can offer guidance in exploring relevant literature and focusing on seminal works that may provide useful directions. Notably, *the 2012 21st International Conference on Computer Communications and Networks* has garnered significant attention from researchers, establishing a “hot research cycle.” Therefore, researchers and practitioners are encouraged to pay special attention to the documents presented at this conference when conducting their literature reviews.

On October 7, 2022, the researchers conducted a search in the Core Collection of Web of Science using the keywords “metaverse*” (topic) and “educat* OR learn* OR teach*” (topic), excluding early access articles (n=10). The search yielded 111 results. The top publications included IEEE Access (n=6), Sustainability (n=5), Electronics (n=4), 2022 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops VRW 2022 (n=3), Applied Sciences Basel (n=3), Procedia Computer Science (n=3), 6th International Conference of Education Research and Innovation ICERI 2013 (n=2), British Dental Journal (n=2), Human Centric Computing and Information Sciences (n=2), IBERIAN Conference on Information Systems and Technologies (n=2), IEEE Global Engineering Education Conference (n=2), Information (n=2), International Journal of Emerging Technologies in Learning (n=2), Journal of Educational Evaluation for Health Professions (n=2), Lecture Notes in Business Information Processing (n=2), Proceedings of the 3rd European Conference on Games Based Learning (n=2), and Sensors (n=2).

Figure 2 illustrates the citation networks stemming from Stephenson’s groundbreaking novel (1992), which coined the term “metaverse” and envisioned its transformation from imagination to reality. Despite its utopian portrayal in fiction, the concept of the metaverse has evolved into a heterotopia that connects the virtual world with the real world, as per scientific opinion. This novel presents seemingly limitless possibilities for the metaverse while also considering the ethical implications of its development in education, economics, and cultural communication. The original exploration of the metaverse laid a solid foundation for its educational applications by seamlessly blending virtual and real worlds. As evidenced in Table 4, it is thus unsurprising that Stephenson’s novel is the most frequently cited literature and serves as a trailblazer in the use of the metaverse for educational purposes.

Using clustering techniques in CitNetExplorer, the literature obtained was classified into a single cluster focused on the application of the metaverse in education. Given that only one cluster was identified, it is apparent that relatively fewer studies have been conducted on this topic. Specifically, the top 100 cited publications from 1993 to 2008 contained few studies investigating the use of the

Table 2. The top ten authors, organizations, and countries based on citations

N	Author	Document	Citation	Total Link Strength	N	Author	Document	Citation	Total Link Strength
1	Allison, Colin	2	1273	5	6	Boughzala, Imed	1	33	2
2	Miller, Alan	2	1273	5	7	De Vreede, Gert-Jan	1	33	2
3	Oliver, Iain	2	1273	5	8	Limayem, Moez	1	33	2
4	Barry, Dana M	4	33	21	9	Fukumura, Yoshimi	4	31	23
5	Kanematsu, Hideyuki	4	33	21	10	Dietrich, Nicolas	1	30	1
N	Organization	Document	Citation	Total Link Strength	N	Organization	Document	Citation	Total Link Strength
1	University of St Andrews	2	1273	1	6	Korea University	1	30	1
2	Clarkson University	4	33	15	7	Sejong University	1	30	1
3	University of Nebraska	1	33	1	8	Université de Toulouse	1	30	1
4	University of South Florida	1	33	1	9	National Institute of Technology (KOSEN), Suzuka College	3	23	12
5	Agrupamento de Escolas João de Deus	1	30	1	10	Nagaoka University of Technology	2	21	7
N	Country	Document	Citation	Total Link Strength	N	Country	Document	Citation	Total Link Strength
1	Scotland	2	1273	1	6	Japan	8	34	7
2	South Korea	21	91	31	7	Portugal	2	30	1
3	USA	17	72	33	8	China	20	22	37
4	Columbia	6	39	4	9	Spain	10	21	33
5	France	4	35	30	10	England	8	16	26

metaverse in education. However, since 2009, researchers have gradually increased their interest in exploring the educational potential of the metaverse, culminating in a peak in related studies in 2022. The retrieved publications suggest that the metaverse has the potential to create immersive and intelligent environments (e.g., Marmaridis & Griffith, 2009; Park & Kim, 2022), enhance interactions (Park, 2021), foster positive attitudes toward learning (Almarzouqi et al., 2022), and improve educational outcomes (Anaconda et al., 2019).

Table 3. The top ten keywords, documents, and sources based on occurrences and citations

N	All Keywords	Occurrence	Total Link Strength	N	All Keywords	Occurrence	Total Link Strength
1	Metaverse	63	508	6	Education	11	106
2	Virtual reality	22	200	7	Artificial intelligence	9	101
3	Augmented reality	15	160	8	Mixed reality	8	90
4	Virtual worlds	13	121	9	Virtual-reality	7	77
5	Second life	13	79	10	Avatar	7	71
N	Document	Citations	Links	N	Document	Citations	Links
1	Oliver (2012)	1264	0	6	Gonzalez Crespo (2013)	15	1
2	Boughzala (2012)	33	0	7	Kanematsu (2014)	11	6
3	Park (2022b)	30	5	8	Siyaev (2021a)	11	3
4	Estudante (2020)	16	1	9	Kye (2021)	11	2
5	Hassouneh (2015)	15	1	10	Kanematsu (2010)	10	3
N	Source	Document	Citations	N	Source	Document	Citations
1	2012 21 st international conference on computer communications and Networks	1	1264	6	Sustainability	5	15
2	IEEE Access	6	33	7	Expert Systems with Applications	1	15
3	Journal of the association for information systems	1	33	8	International Journal of Emerging Technologies in Learning	2	13
4	Journal of Chemical Education	1	30	9	Journal of Educational Evaluation for Health Professions	2	12
5	Journal of Electronic Commerce Research	1	16	10	Knowledge-based and Intelligent Information & Engineering Systems	1	11

RQ4: What educational environments can the metaverse create?

The metaverse offers a range of collaborative, smart, immersive, and synthetic environments for educational purposes. Metaverse technologies can establish a platform where smart learning environments connect both physical and virtual worlds. For instance, in the metaverse, a digital-twin smart home serves as a vital platform for immersive communication between the physical and virtual world (Yang et al., 2022). Synthetic learning environments in the metaverse can provide abundant learning resources and social networks, integrating learners into educational systems (Pinchuk et al., 2017). Metaverse-based learning can significantly enhance learning and teaching effectiveness by

Figure 2. Citation networks of obtained the top 100 cited publications via CitNetExplorer

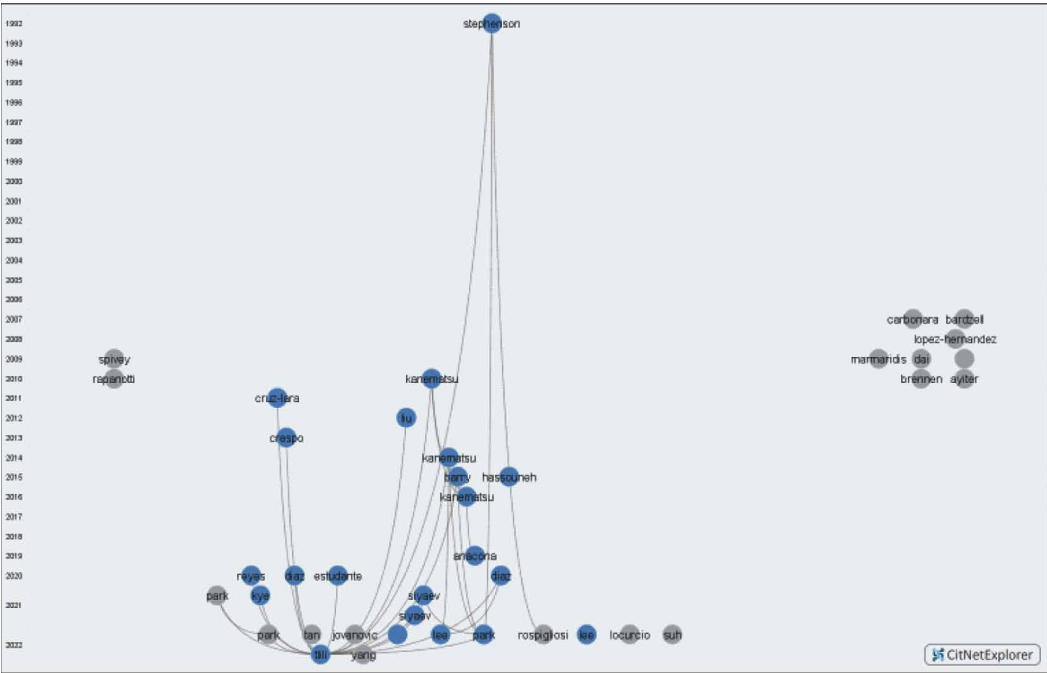


Table 4. Highlights of visualized literature in the highly cited publications

Item	Publication Year	Number of Citations	First Author	Title
Pioneer	1992	10	Stephenson, N.	Snow Crash
Highest citation score	1992	10	Stephenson, N.	Snow Crash
Most recent	2022	5	Park, S.M.	A Metaverse: Taxonomy, Components, Applications, and Open Challenges
Topic discussion	Starting from a coined term in the novel, the metaverse has been developed to contain hardware, software, and contents based on user interaction, implementation, and application.			
Overall conclusion	The metaverse can greatly influence society and human beings, but it is limited to sustainability, hardware, software, development, and open challenges.			

providing immersive and 3D learning environments, thus improving learner experiences (Marmaridis & Griffith, 2009). Through the integration of various technologies, the metaverse can change imagination into reality, creating diverse learning environments and activities such as survival scenarios, maze exploration, multiple-choice assessments, running, and chasing games (Park & Kim, 2022). The metaverse, with its educational potential and technological capabilities, can offer novel solutions to meet the evolving needs of modern education.

RQ5: Can the use of the metaverse enhance interactions?

The metaverse has the potential to enhance interactions and improve educational outcomes. By providing social networks, the metaverse can facilitate interaction in foreign language learning, allowing learners the freedom to develop their imagination (Liu & Zhang, 2011). Through enhanced interactions, the metaverse can improve collaborative and dynamic learning environments, thereby enhancing learning motivation and efficiency (Tarouco et al., 2013). Interactions in the metaverse occur between real, virtual, and mixed targets, with mixed interactions establishing a learning community where learners can communicate, learn, and share despite different venues and geographical barriers (Araya et al., 2018). For example, two metaverse platforms, Second Life and Solipsis, can improve multilingual interactions and enhance language learning outcomes (Cruz-Lara et al., 2011). By bridging the gap between physical and virtual realities, the metaverse can blur the differences between virtual reality and physical reality using technologies such as augmented reality, virtual worlds, and serious games. Furthermore, the metaverse can enhance Korean language educational outcomes by improving interactions (Park, 2021). The metaverse offers unique opportunities for learners to interact, collaborate, and learn, ultimately improving educational outcomes.

RQ6: Can the use of the metaverse improve educational outcomes?

The metaverse presents a range of modern teaching methods through virtual reality technologies that can improve educational outcomes (Anaconda et al., 2019). Integrating social networks into the metaverse has the potential to significantly enhance educational outcomes (Ribeiro et al., 2013). A platform utilizing virtual reality, augmented reality techniques, deep learning technologies, and metaverse content can identify learners' satisfaction levels, learning experiences, and presence in the learning environment (Cho et al., 2022). The use of augmented reality technologies based on the mobile metaverse has proven effective in improving mathematics performance among students in Mexico (Reyes, 2020). In problem-based metaverse classes, avatars with blinking systems can identify users' emotions and responses to challenging mathematics problems, enabling teachers to adopt appropriate teaching strategies to improve learning outcomes (Barry et al., 2015). Through the integration of various technologies, the metaverse holds considerable potential for revolutionizing traditional teaching methods and improving educational outcomes.

RQ7: Can the use of the metaverse cultivate positive learning attitudes toward education?

The majority of literature on the use of the metaverse in education reports positive learning attitudes. In the United Arab Emirates, students' satisfaction with the metaverse positively predicts their intention to use it for medical education (Almarzouqi et al., 2022). Students who have experienced metaverse-based learning evaluate its role in learning more positively than traditional and room-based synchronous learning (Nishino et al., 2012). The use of metaverse-based virtual reality technologies can effectively transmit Chinese culture to students and provide an animated experience of the culture (Shen, 2022). This virtual-real experience with cultures undoubtedly cultivates positive learning attitudes toward the use of the metaverse in education. Culture-integrated learning experiences can enhance learners' confidence in their cultural identity, thereby strengthening their positive attitudes toward the use of the metaverse in education.

RQ8: What are the challenges in the use of the metaverse in education?

Despite its potential benefits, the use of the metaverse in education is still confronted with numerous challenges. Improper interactions and inappropriate device usage may result in negative educational outcomes (Cheong & Lee, 2022). Teachers may be unfamiliar with metaverse-based

teaching methods, and limited training has been implemented to address this issue. More collaboration and experiences are necessary to improve metaverse-based educational outcomes, given that interdisciplinary teaching based on the metaverse has seldom been practiced. Another concern is the ethical use of the metaverse in education, as personal information, identity, and privacy appear difficult to protect within a metaverse context. Cultural shock may also pose a potential threat to the efficacy of metaverse-based learning environments (Ortega-Rodriguez, 2022). Addressing these challenges is crucial for maximizing the potential benefits of the metaverse in education while minimizing potential risks.

Researchers should also consider various challenges related to the use of metaverse technologies in education, including societal and political issues, communication and collaboration, education and learning, technology, and ethics and law (Hendaoui et al., 2008). The use of the metaverse may require users to shift between augmented and virtual technologies, resulting in high costs and significant inconvenience in education. Moreover, data collection based on individual learning behaviors and personal information can exacerbate concerns about privacy and security. Crimes may occur and be challenging to detect due to the online anonymous identity in the metaverse. To address these issues, a double-check avatar system may be necessary to filter suspicious behaviors. Furthermore, it may be essential to establish a metaverse world with ethical standard reminders, where avatars can set up models for learners to abide by ethical criteria (Park & Kim, 2022). Addressing these challenges is critical for enhancing the effectiveness and safety of metaverse-based education.

DISCUSSION

It is evident that the metaverse can offer educational benefits with regards to environments, interactions, learning outcomes, and attitudes. The use of the metaverse requires the creation of virtual and physical environments that represent one another simultaneously. With proper digital competencies, educators can combine virtual and physical environments to enhance educational outcomes (Tlili et al., 2022). Metaverse technologies are equipped with sensing abilities that enable lower-cost and sensitive capturing techniques in virtual environments, effectively supervising student attendance and encouraging their participation in learning activities (Wang et al., 2022). Log data collected in metaverse environments can also help teachers supervise students' learning behaviors and encourage active participation in learning activities when necessary. Furthermore, the metaverse has demonstrated its efficacy in improving educational outcomes by connecting real and virtual environments and enhancing learning outcomes in simulated virtual environments (Siyaev & Jo, 2021b).

The Lifelogging Metaverse combines augmented reality with communicative interactions (Siyaev & Jo, 2021a) to provide timely feedback and enhance educational outcomes (Kye et al., 2021). The platform allows students to retrieve abundant data and exchange information with their peers. Convenient interactions and 3D virtual reality technologies motivate students to acquire knowledge through the metaverse (Pereira et al., 2015). Teachers can offer a plethora of learning resources on the metaverse platform that students can download or share freely and conveniently (Díaz et al., 2020). Social networks on the metaverse platform enable students to interact with each other and obtain information from peers, enhancing collaborative learning effectiveness (Díaz et al., 2020).

Interactions are a crucial factor that can be enhanced by the use of the metaverse, resulting in improved educational outcomes. Non-verbal cues exhibited by metaverse avatars, such as gestures, body movements, eye contact, gaze, and facial expressions, can enhance interactions in educational contexts (Bailenson et al., 2002). The combination of virtual and physical realities can further improve learning interactions, which can be leveraged to enhance education and improve outcomes. The rich learning experiences, strong customization, ostensive creativity, and high security offered by the metaverse can strengthen learning interactions, enhance motivation, encourage learning engagement, and outperform traditional learning methods (Cai & Liu, 2022). However, the use of the metaverse in education also poses potential risks. For instance, the risk of personal information revelation

remains higher and more difficult to resolve through the use of metaverse technologies compared to traditional learning methods.

The metaverse provides a solid foundation for student-centered education and cultivates positive learning attitudes based on the constructivism theory (Clark, 2018). Learning experiences and attitudes are connected to learners' perceptions of new knowledge and information through metaverse technologies, enhancing their positive attitudes toward the metaverse and promoting educational outcomes (Suh & Ahn, 2022). Nevertheless, a study has reported a gender gap in attitudes toward the use of the metaverse in education, with females exhibiting more positive attitudes towards life-logging used in education than their male counterparts. These attitudes may be influenced by other factors, such as personalities, rewards, and gamification (Codish & Ravid, 2014). When educators, designers, and policymakers address solutions to bridge this gender gap in attitudes toward the use of the metaverse in education, they should consider various influencing factors (Suh & Ahn, 2022).

CONCLUSION

Major Findings

This study fills a gap in the literature by conducting a bibliometric analysis of research on the use of the metaverse in education, using both VOSviewer and CitNetExplorer. The analysis identified the most prolific authors, organizations, and countries, as well as the most frequently used keywords, documents, and sources. Additionally, the study examined the research trend and challenges associated with using the metaverse in education, along with the effects of the metaverse on learning environments, interactions, educational outcomes, and learning attitudes. The results of this study provide a solid foundation and serve as a valuable reference for future research on the use of the metaverse in education.

Limitations

Despite using two established programs, this study has several limitations. Firstly, due to limited library resources, it was not possible to include all relevant literature. Secondly, the findings were based on literature retrieved through the aforementioned programs, which may have resulted in publication bias. Thirdly, the research relied solely on secondary sources, highlighting the need for primary data to complement and enrich these findings. Finally, since most of the evidence was drawn from previous studies, the reliability of the findings may be compromised.

Implications for Future Research

Future research can focus on developing learning management systems to benefit metaverse-based education. Such systems could provide a stable and reliable platform for teachers and learners to transmit knowledge and access learning resources while enabling teachers to monitor learning progress and students' performance (Pigultong & Ieee, 2022). Interdisciplinary research into the use of the metaverse in education is also needed. For instance, cognitive science can inform how to enhance learners' cognitive abilities, motivation, and memory, while computer science can encourage educators to develop immersive and sustainable learning environments (Park & Kim, 2022). Advanced quantum mechanics may also help connect learners to the metaverse in an effective and efficient way, stimulating their curiosity and interest and leading to enhanced creativity and improved learning outcomes.

Future research can also investigate the complex interplay of different types of metaverse technologies in education, highlighting the gap between augmentation, intimate interactions, simulation, and external interaction technologies (Tlili et al., 2022). The appropriate integration of different metaverse technologies, such as augmented reality, lifelogging, mirror world, and virtual reality, may significantly improve human-computer interactions and artificial intelligence, making education more accessible and effective. To overcome the barriers to the integration of metaverse technologies, teachers, learners, technicians, developers, and designers must collaborate. In the future,

textbooks, courses, delivery modes, and educational environments are likely to undergo dramatic changes. Both students and teachers must prepare themselves for these changes by improving their digital literacy and keeping pace with the development of metaverse technologies.

ACKNOWLEDGMENT

This work is supported by 2019 MOOC of Beijing Language and Culture University (MOOC201902) (Important) “Introduction to Linguistics”; “Introduction to Linguistics” of online and offline mixed courses in Beijing Language and Culture University in 2020; Special fund of Beijing Co-construction Project-Research and reform of the “Undergraduate Teaching Reform and Innovation Project” of Beijing higher education in 2020-innovative “multilingual +” excellent talent training system (202010032003); The research project of Graduate Students of Beijing Language and Culture University “Xi Jinping: The Governance of China” (SJTS202108).

DECLARATIONS

Disclosures and Declarations: The author declares that there are no funding and/or conflicts of interests/competing interests.

Availability of Data and Material: We make sure that all data and materials support our published claims and comply with field standards.

The Ethical Approval Statement: The study has been approved by the ethical committee of the author institution.

REFERENCES

- Almarzouqi, A., Aburayya, A., & Salloum, S. A. (2022). Prediction of User's Intention to Use Metaverse System in Medical Education: A Hybrid SEM-ML Learning Approach. *IEEE Access : Practical Innovations, Open Solutions*, 10, 43421–43434. doi:10.1109/ACCESS.2022.3169285
- Anacona, J. D., Millan, E. E., & Gomez, C. A. (2019). Application of metaverses and the virtual reality in teaching. *Entre Ciencia E Ingenieria*, 25, 59-67. 10.31908/19098367.4015
- Araya, N. M. M., & Avila, R. S. H. (2018). *Collaborative learning through integration of environments real and virtual-immersive*. In 2018 37th International Conference of the Chilean Computer Science Society (SCCC), Santiago, Chile. doi:10.1109/SCCC.2018.8705260
- Barry, D. M., Ogawa, N., Dharmawansa, A., Kanematsu, H., Fukumura, Y., Shirai, T., Yajima, K., & Kobayashi, T. (2015). Evaluation For Students' Learning Manner Using Eye Blinking System in Metaverse. *Procedia Computer Science*, 35, 1229-1238. doi:10.1016/j.procs.2015.08.181
- Bhugaonkar, K., Bhugaonkar, R., & Masne, N. (2022). The Trend of Metaverse and Augmented & Virtual Reality Extending to the Healthcare System, *Cureus. Journal of Medical Science*, 14(9). Advance online publication. doi:10.7759/cureus.29071 PMID:36258985
- Cai, W. J., & Liu, Y. (2022). The Value of Immersive Media in Expanding Chinese Public Cultural Participation and Its Realization Path From the Perspective of Cultural Education. *Frontiers in Psychology*, 13, 915913. Advance online publication. doi:10.3389/fpsyg.2022.915913 PMID:35837631
- Cheong, Y., & Lee, Y. H. (2022). A Case Study on Elementary Convergence Education Using Metaverse Platform. *The Journal of Learner-Centered Curriculum and Instruction*, 22(16), 561–580.
- Cho, Y., Hong, S., Kim, M., & Kim, J. (2022). DAVE: Deep Learning-Based Asymmetric Virtual Environment for Immersive Experiential Metaverse Content. *Electronics (Basel)*, 11(16), 2604. doi:10.3390/electronics11162604
- Clark, K. R. (2018). Learning theories: Constructivism. *Radiologic Technology*, 90(2), 180–182. PMID:30420576
- Codish, D., & Ravid, G. (2014). Academic course gamification: The art of perceived playfulness. *Interdisciplinary Journal of e-Skills and Lifelong Learning*, 10, 131–51. 10.28945/2066
- Cruz-Lara, S., Osswald, T., Guinaud, J., Bellaleme, N., Bellaleme, L., & Camal, J. P. (2011). A Chat Interface Using Standards for Communication and e-Learning in Virtual Worlds. In *Enterprise Information Systems. ICEIS 2010. Lecture Notes in Business Information Processing* (vol. 73). Springer. doi:10.1007/978-3-642-19802-1_37
- Dahan, N. A., Al-Razgan, M., Al-Laith, A., Alsoufi, M. A., Al-Asaly, M. S., & Alfakih, T. (2022). Metaverse Framework: A Case Study on E-Learning Environment (ELEM). *Electronics (Basel)*, 11(10), 1616. doi:10.3390/electronics11101616
- Diaz, J. E. M., Saldana, C. A. D., & Avila, C. A. R. (2020). Virtual World as a Resource for Hybrid Education. *International Journal of Emerging Technologies in Learning*, 15(15), 94–109. doi:10.3991/ijet.v15i15.13025
- Getchell, K., Oliver, I., Miller, A., Allison, C., & Soc, I. C. (2010). Metaverses as a Platform for Game Based Learning. In *24th IEEE International Conference on Advanced Information Networking and Applications*. IEEE. doi:10.1109/AINA.2010.125
- Guo, H. Y., & Gao, W. R. (2022). Metaverse-Powered Experiential Situational English-Teaching Design: An Emotion-Based Analysis Method. *Frontiers in Psychology*, 13, 859159. doi:10.3389/fpsyg.2022.859159 PMID:35401297
- Hendaoui, A., Limayem, M., & Thompson, C. W. (2008). 3D social virtual worlds-Research issues and challenges. *IEEE Internet Computing*, 12(1), 88–92. doi:10.1109/MIC.2008.1
- Hines, P., & Netland, T. H. (2022). Teaching a Lean masterclass in the metaverse. *International Journal of Lean Six Sigma*. Advance online publication. doi:10.1108/IJLSS-02-2022-0035
- Iwanaga, J., Muo, E. C., Tabira, Y., Watanabe, K., Tubbs, S. J., D'Antoni, A. V., Rajaram-Gilkes, M., Loukas, M., Khalil, M. K., & Tubbs, R. S. (2022). Who really needs a Metaverse in anatomy education? A review with preliminary survey results. *Clinical Anatomy (New York, N.Y.)*. Advance online publication. doi:10.1002/ca.23949 PMID:36087277

- Jaramillo-Mujica, J. A., Morales-Avella, L. F., & Coy-Mondragon, D. M. (2017). An experience using metaverses for teaching mechanical physics to engineering students. *Revista Educacion En Ingenieria*, 12(24), 20–30. doi:10.26507/rei.v12n24.778
- Jovanovic, A., & Milosavljevic, A. (2022). VoRtex Metaverse Platform for Gamified Collaborative Learning. *Electronics (Basel)*, 11(3), 317. doi:10.3390/electronics11030317
- Kanematsu, H., Kobayashi, T., Barry, D. M., Fukumura, Y., Dharmawansa, A., & Ogawa, N. (2014). Virtual STEM class for nuclear safety education in metaverse. *Procedia Computer Science*, 35, 1255–1261. doi:10.1016/j.procs.2014.08.224
- Kye, B., Han, N., Kim, E., Park, Y., & Jo, S. (2021). Educational applications of metaverse: Possibilities and limitations. *Journal of Educational Evaluation for Health Professions*, 18, 1–13. doi:10.3352/jeehp.2021.18.32 PMID:34897242
- Kye, B., Han, N., Kim, E., Park, Y., & Jo, S. (2021). Educational applications of Metaverse: Possibilities and limitations. *Journal of Educational Evaluation for Health Professions*, 32, 32. Advance online publication. doi:10.3352/jeehp.2021.18.32 PMID:34897242
- Lee, H., & Hwang, Y. H. (2022). Technology-Enhanced Education through VR-Making and Metaverse-Linking to Foster Teacher Readiness and Sustainable Learning. *Sustainability*, 14(8), 4786. doi:10.3390/su14084786
- Lee, H., Woo, D., & Yu, S. (2022). Virtual Reality Metaverse System Supplementing Remote Education Methods: Based on Aircraft Maintenance Simulation. *Applied Sciences-Basel*, 12(5), 2667. doi:10.3390/app12052667
- Lee, S. H., Lee, H., & Kim, J. H. (2022). Enhancing the Prediction of User Satisfaction with Metaverse Service Through Machine Learning. *CMC-Computers Materials & Continua*, 72(3), 4983–4997. doi:10.32604/cmc.2022.027943
- Li, H. Y., Cui, C. H., & Jiang, S. (2022). Strategy for improving the football teaching quality by AI and metaverse-empowered in mobile internet environment. *Wireless Networks*. Advance online publication. doi:10.1007/s11276-022-03000-1
- Liu, X. H., & Zhang, J. X. (2011). Foreign Language Learning through Virtual Communities. *Energy Procedia*, 17, 737–740. doi:10.1016/j.egypro.2012.02.165
- Marmaridis, I., & Griffith, S. (2009). Metaverse Services: Extensible Learning with Mediated Teleporting into 3D Environments. In *Information Systems: Modeling, Development, and Integration*. UNISCON 2009. Springer. doi:10.1007/978-3-642-01112-2_24
- Nishino, K., Mayumi, T., Iribe, Y., Mizuno, S., Ogawa, N., Yajima, K., Aoki, K., & Fukumura, Y. (2012). Consideration on the Relationship between Changes in Learners' Learning Preferences and the Differences in e-Learning Modes of a Course. *Frontiers in Artificial Intelligence and Applications*, 243, 1121–1130. doi:10.3233/978-1-61499-105-2-1121
- Ortega-Rodriguez, P. J. (2022). From extended reality to the metaverse: A critical reflection on contributions to education. *Teoría de la Educación: Revista Interuniversitaria*, 34(2), 189–208. doi:10.14201/teri.27864
- Park, J. (2021). Exploring the Possibility of Using Metaverse in Korean Language Education. *Journal of the International Network for Korean Language and Culture*, 18(3), 117–146. doi:10.15652/ink.2021.18.3.117
- Park, S., & Kim, S. (2022). Identifying World Types to Deliver Gameful Experiences for Sustainable Learning in the Metaverse. *Sustainability*, 14(3), 1361. doi:10.3390/su14031361
- Park, S. M., & Kim, Y. G. (2022). A Metaverse: Taxonomy, Components, Applications, and Open Challenges. *IEEE Access : Practical Innovations, Open Solutions*, 10, 4209–4251. doi:10.1109/ACCESS.2021.3140175
- Pereira, C. E., Paladini, S., & Schaf, F. M. (2015). 3D autosyslab prototype-a social, immersive and mixed reality approach for collaborative learning environments. *International Journal of Engineering Pedagogy*, 2(2), 15. doi:10.3991/ijep.v2i2.2083
- Pigultong, M. (2022). *Cognitive Impacts of Using a Metaverse embedded on Learning Management System for Students with Unequal Access to Learning Resources*. 2022 10th International Conference on Information and Education Technology (ICIET 2022), Matsue, Japan. 10.1109/ICIET55102.2022.9779045

- Pinchuk, O. P., Lytvynova, S. G., & Burov, O. Y. (2017). Synthetic Educational Environment-A Footpace to New Education. *Information Technologies and Learning Tools*, 60(4), 28–45. doi:10.33407/itlt.v60i4.1831
- Rapanotti, L., & Hall, J. G. (2010). Lessons learned in developing a Second Life educational environment. *Proceedings of the 2nd International Conference on Computer Supported Education*. <http://www.csedu.org/>
- Reyes, C. E. G. (2020). Perception of high school students about using Metaverse in augmented reality learning experiences in mathematics. *Pixel-Bit-Revista De Medios Y Educacion*, 58, 143-159. 10.12795/pixelbit.74367
- Ribeiro, R., Mandaji, M., Camas, N., Tercariol, A., Silva, R., & Mengalli, N. (2013). Paths to Innovative Pedagogical Practices for Learning and Teaching: An Analysis Considering the I and II Web Curriculum Seminars. *6th International Conference of Education, Research and Innovation (ICERI 2013)*, 2589-2597.
- Schlemmer, E., & Marson, F. (2013). Immersive Learning: Metaverses and Digital Games in Education. *Proceedings of the 2013 8th Iberian Conference on Information Systems and Technologies (CISTI 2013)*.
- Shen, S. Y. (2022). Metaverse-driven new energy of Chinese traditional culture education: Edge computing method. *Evolutionary Intelligence*. Advance online publication. doi:10.1007/s12065-022-00757-4
- Siyaev, A., & Jo, G. S. (2021a). Neuro-symbolic speech understanding in aircraft maintenance metaverse. *IEEE Access : Practical Innovations, Open Solutions*, 9, 154484–154499. doi:10.1109/ACCESS.2021.3128616
- Siyaev, A., & Jo, G. S. (2021b). Towards aircraft maintenance Metaverse using speech interactions with virtual objects in mixed reality. *Sensors (Basel)*, 21(6), 2066. doi:10.3390/s21062066 PMID:33804253
- Stephenson, N. (1992). *Snow Crash: A Novel*. Del Rey, Penguin Random House LLC.
- Suh, W., & Ahn, S. (2022). Utilizing the Metaverse for Learner-Centered Constructivist Education in the Post-Pandemic Era: An Analysis of Elementary School Students. *Journal of Intelligence*, 10(1), 17. doi:10.3390/jintelligence10010017 PMID:35324573
- Tarouco, L., Gorziza, B., Correa, Y., Amaral, E. M. H., & Muller, T. (2013). *Virtual Laboratory for Teaching Calculus: an Immersive Experience*. 2013 IEEE Global Engineering Education Conference (EDUCON), IEEE Global Engineering Education Conference (EDUCON). Tech Univ Berlin, Berlin, Germany.
- Tlili, A., Huang, R. H., Shehata, B., Liu, D. J., Zhao, J. L., Metwally, A. H. S., Wang, H. H., Denden, M., Bozkurt, A., Lee, L. H., Beyoglu, D., Altinay, F., Sharma, R. C., Altinay, Z., Li, Z. S., Liu, J. H., Ahmad, F., Hu, Y., Salha, S., & Burgos, D. et al. (2022). Is Metaverse in education a blessing or a curse: A combined content and bibliometric analysis. *Smart Learning Environments*, 9(24), 1–31. doi:10.1186/s40561-022-00205-x
- Van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, 84(2), 523–538. doi:10.1007/s11192-009-0146-3 PMID:20585380
- Van Eck, N. J., & Waltman, L. (2014a). CitNetExplorer: A new software tool for analyzing and visualizing citation networks. *Journal of Informetrics*, 8(4), 802–823. doi:10.1016/j.joi.2014.07.006
- Van Eck, N. J., & Waltman, L. (2014b). Visualizing bibliometric networks. In Y. Ding, R. Rousseau, & D. Wolfram (Eds.), *Measuring scholarly impact: Methods and practice*. Springer. doi:10.1007/978-3-319-10377-8_13
- Wagner, R., Passerino, L. M., Piovesan, S. D., & de Lima, J. V. (2013). *Using 3D Virtual Learning Environments in New Perspective of Education*. 12th International Conference on Information Technology Based Higher Education and Training (ITHET), International Conference on Information Technology Based Higher Education and Training, Antalya, Turkey. doi:10.1109/ITHET.2013.6671019
- Wang, Y., Lee, L. H., Braud, T., & Hui, P. (2022). Re-shaping Post-COVID-19 teaching and learning: A blueprint of virtual-physical blended classrooms in the metaverse era. In *The 1st International Workshop on Social and Metaverse Computing and Networking in conjunction with IEEE ICDCS'22*, Bologna, Italy. doi:10.1109/ICDCSW56584.2022.00053
- Yang, Y. Q., Shi, Q. F., Zhang, Z. X., Shan, X. C. A., Salam, B., & Lee, C. (2022). Robust triboelectric information-mat enhanced by multi-modality deep learning for smart home. *Informat*, e12360. 10.1002/inf2.12360

Wentao Chen (First Author), Professor in Zhejiang Yuexiu University, has already published over 20 academic papers (mainly peer reviewed international articles) on distinguished journals based on rich teaching and research experiences. His research interest includes educational technologies, language attrition, and language acquisition.

Jinyu Zhang (Second Author), Associate Professor in Zhejiang Yuexiu University, a Master-degree holder in Applied Linguistics and has already published over 10 papers on distinguished journals based on rich teaching and research experiences. Her research interest includes educational technologies and language acquisition.

Zhonggen Yu, (Corresponding author), ORCID: 0000-0002-3873-980X, Professor (Distinguished) and Ph.D. Supervisor in Department of English Studies, Faculty of Foreign Studies, Beijing Language and Culture University, has already published over 120 academic papers in distinguished journals based on rich teaching and research experiences. His research interest includes educational technologies, language attrition, and language acquisition. He is Editor in Chief of International Journal of Technology-Enhanced Education and Academic Editor of Education Research International. Email: 401373742@qq.com; yuzhonggen@blcu.edu.cn.