PERSPECTIVES OF SCIENCE AND EDUCATION
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SCIENTIFIC ARTICLE |

Review of Metaverse in Education: Unleashing Classroom Boundaries

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ABSTRACT

Introduction. The emergence of the Metaverse has revolutionized education by offering immersive and interactive learning experiences, transcending traditional classroom boundaries. As a convergence of physical and digital realities, the Metaverse in Education (MVE) enables personalized, blended, and distance learning, attracting significant scholarly attention. This study aims to map the potential of MVE, identifying trends, key contributors, and focus to understand its potential and challenges in education.

Methods. This study used bibliometric analysis and systematic literature review of 123 Scopus-indexed publications (2011-2023) to address four objectives:1) identify productive countries, affiliations, and authors in MVE research, 2) analyze influential sources and citation trends, 3) examine thematic clusters and keyword co-occurrence, and 4) highlight research gaps. Data were extracted using VOSviewer for network visualization and synthesized through PRISMA guidelines for an in-depth literature and methodology review.

Results. The research analysis revealed that China and South Korea are the main pioneers in the development of Metaverse for Education (MVE), with the Smart Learning Institute of Beijing Normal University as the most productive institution. The study findings show three main application areas of MVE: 1) integration of immersive technologies such as VR/AR and gamification, 2) pedagogical innovations based on constructivism, and 3) sustainable education approaches. The implementation of MVE has proven to be effective in increasing student engagement, global collaboration, and expanding access to education. However, the main challenge in the adoption of MVE lies in the readiness of educators, so a comprehensive teacher training program is needed, including mastery of digital platforms, immersive learning design, and virtual reality-based evaluation strategies. The implementation of this training needs to be supported by the development of adequate infrastructure, clear policy frameworks, and cybersecurity standards to ensure sustainable and equitable implementation of MVE in various regions.

Practical significance. This research provides actionable insights for educators, policymakers and researchers. The findings confirm the potential of MVEsin supporting 21st century skills development and continuing education, while recommending inclusive implementation strategies. The study results also provide a foundation for further research, especially in addressing the technology gap and the long-term impact of MVE adoption.

KEYWORDS

metaverse, education, bibliometric, VOSviewer

For Citation: Prahani, B. K., Rizki, I. A., & Kurtulus, M. A. (2026). Review of Metaverse in Education: Unleashing Classroom Boundaries. *Perspektivy nauki i obrazovania = Perspectives of Science and Education*, (1), 10–22. https://doi.org/10.32744/pse.2026.1.1

Received: 12 August 2025 | Approved: 13 Ocober 2025 | Published: 28 February 2026

INTRODUCTION

Currently, there is a revolution in the field of education with the emergence of various sophisticated technologies that intervene in the learning process, one of which is the metaverse [1; 2]. The emergence of the Metaverse in Education (MVE) holds the potential to revolutionize the way of learn, teach, and interact within educational settings. The metaverse refers to a collective virtual shared space, created by the convergence of physical and digital reality, where users can engage with each other and computer-generated environments in real-time [3]. This trend is envisaged to grow continuously in the future, along with the development of digital technology, such as artificial intelligence, augmented and virtual reality, the Internet of Things, and e-learning [4].

The MVE concept is believed to grow immensely because the metaverse allows for the creation of highly immersive and interactive learning environments. Students can engage with subjects through virtual simulations, 3D models, and interactive scenarios, enhancing their understanding and retention of complex concepts [5; 6]. Pupils can access classes, resources, and social interactions from the comfort of their own spaces. Due to its potential to enhance learning experiences, increase engagement, and expand educational opportunities, it makes an exciting avenue for the future of education.

The metaverse's application in education has rapidly progressed from games for pleasure to serious games for education, bringing both obstacles and opportunities for teachers and students. The metaverse has attracted attention as an innovative technology with potential benefits as reality-based technology has advanced [7]. Empirically, research on MVE has undergone significant developments as evidenced by MVED research in various multidisciplinary fields, such as medicine [8], electrical engineering [9], inclusive education [10], physical education [11], dental education [12], and mathematics learning [13]. Moreover, users have a good learning attitude toward the metaverse when it is employed in education. Education, navigation, and mobile services can all be provided using metaverse technologies. Because of their simplicity and accessibility, mobile metaverse applications have grown in popularity. Consequently, in order to correlate the findings of the study and determine the direction of emerging research direction, bibliometric analysis of the literature is needed [14].

Until now, few studies have conducted a bibliographic review on and a chronological trend in the use of the MVE. Thus, this study conducts a bibliometric review in order to visualize and map the research profiles and emerging trends in MVE. This research entails providing information to researchers, educational institutions, teachers, and librarians about the future direction of research in MVE, and exploring how the virtualization of the learning process happens through MVE. Our proposed research questions are mentioned as follows:

RQ1: What are the top productive countries and affiliations of MVE publications?

RQ2: What are the scholars' profiles and source titles of MVE publications?

RQ3: What was discussed in the most influential documents of MVE publication?

RQ4: What are the keywords trend and their visualizations mapping of MVE publication?

THEORETICAL BACKGROUND

Intriguingly, the first publication of MVE ensued in 2011 entitled “Language learning resources and developments in the Second Life metaverse” [15], where they suggest novel second language acquisition strategies and investigate the potential of several pedagogical features in the creation of tandem English/Spanish language courses for specific professional sectors. More about MVE research trends can be seen in Figure 2. In the early years, particularly from 2011 to 2014, there was limited research activity on the metaverse's application to education. With only one article published in 2011 and 2014 each, it indicates that this area was not extensively explored during this period. Even in 2015-2020, there were no MVE scientific publications at all. However, 2021 marked an exciting turning point, with one article published but a significant spike in the average number of total citations per year (14.67). This suggests that while the quantity of research remained

relatively low, the quality of the research might have been notable, leading to higher citation rates. 2022 experienced a dramatic increase in MVE research activity, with 42 articles published. However, the average number of total citations per year slightly decreased to 10.16. Indeed, there are fewer citable years than in previous years, but it is envisaged to increase moderately. The most recent data from 2023 demonstrates a remarkable increase in research output, with 78 articles published. However, the average number of total citations per year dropped significantly to 1.49. This divergence may be because articles that have just been published have a tendency to be unreachable by researchers and do not yet have an impact on the development of MVE research.

This tendency in enormous increases in MVE research trends is possibly due to technological developments, where advances in virtual reality (VR), augmented reality (AR), and related technologies have made the metaverse more accessible and applicable in educational contexts, such as science education [16; 17], social education [18], and engineering education [19]. Moreover, the COVID-19 pandemic accelerated the shift to online and remote learning. This sudden transition prompted educators to explore new methods of delivering content and maintaining student engagement, implying a significant rise of MVE publications between 2021 and 2023. The metaverse offers immersive and interactive experiences that can mitigate the challenges of distance learning [20]. Thus, MVE is envisioned to be a novel research trend, attracting researchers in the next few years.

RESEARCH METHODS

At its most fundamental level, bibliometrics is an approach that utilizes mathematics and statistics to analyze books and other forms of communication media [14]. Bibliometric studies serve as a crucial reference in this study, as they provide a tool for analyzing research across various literary works that have been published [21], closely related to the MVE in this particular study. Several bibliometric techniques are employed to address the research question, encompassing descriptive statistics, co-author analysis, co-citation analysis, co-occurrence analysis, and scientific mapping [22]. The significance of evaluation processes, especially the utilization of bibliometric indicators based on author publication patterns and journal editorial standards, is progressively gaining recognition among the scientific community, publishers, and policymakers.

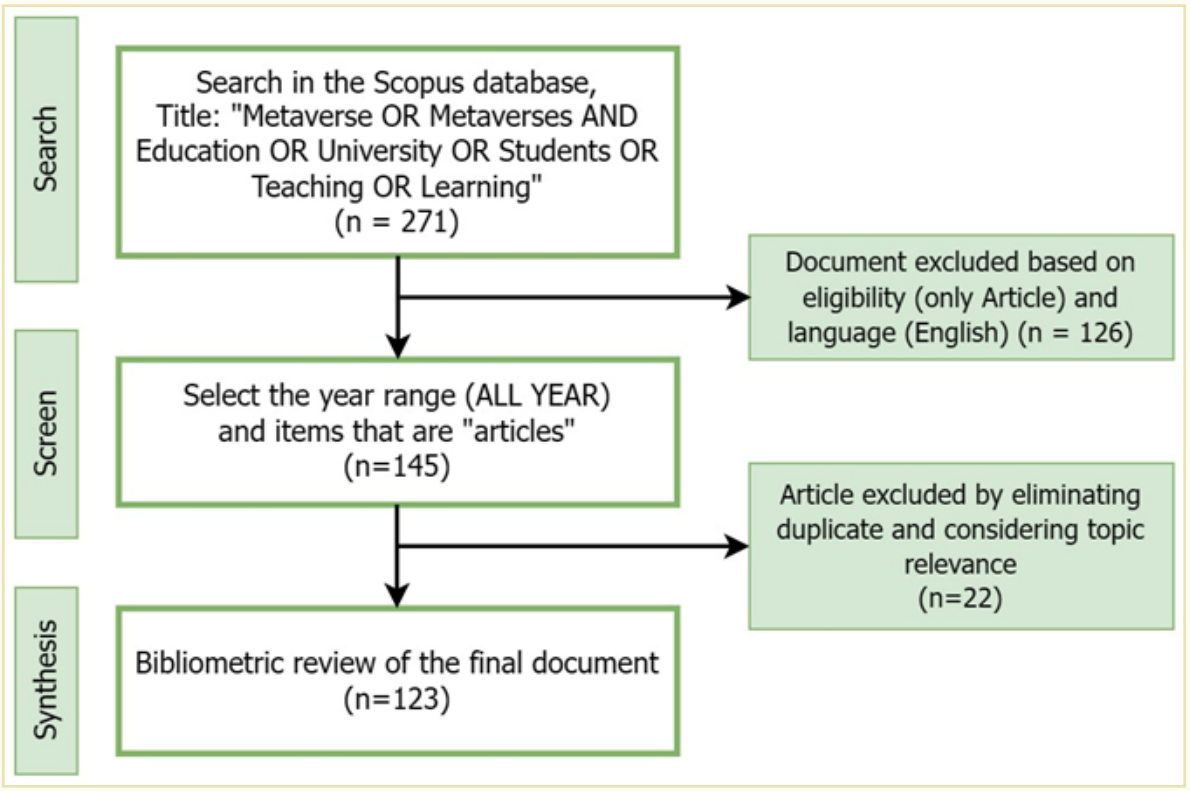

Figure 1 Article selection process and methods

Bibliometric analysis delves into patterns and relationships among authors, keywords, countries, and references to trace the development of the studied topic, in this case, the MVE. Consequently, a robust scientific database is essential to provide such metadata, and Scopus has been employed for this purpose in the current study. The rationale for selecting the Scopus database stems from its extensive coverage of materials, surpassing that of other databases by up to 70% [23]. According to H. E. Chen et al [24], the bibliometric analysis comprises three essential stages: search, screening, and synthesis. The search phase is pivotal in shaping the analysis process, where the search query utilizes keywords such as "Metaverse" and "Metaverse and Education," along with descriptors like "University," "Students," "Teaching," and "Learning." Figure 1 shows article selection process and methods. This search was conducted on August 23, 2023, initially yielding 271 relevant documents. Subsequently, a filtering process was implemented to narrow down the document types, focusing solely on "articles," and documents written in English were retained. The year of publication was not restricted, given the substantial surge in MVE publications. Following this refinement, abstracts were meticulously read to identify duplicates and eliminate topics not directly aligned with MVE. This rigorous screening led to the inclusion of 123 documents for the subsequent bibliometric analysis. To visualize the data, VOSviewer software is used due to the fact that it provides powerful visualization capabilities, allowing the creation of visual representations of bibliometric networks [25; 26]. Moreover, it has a user-friendly interface that makes it easy to navigate and interact with the software, while it yields various analytical views and customization options [27].

RESULTS

1. Top Countries and Affiliations

When it comes to scientific publications by country (Table 1), China is the country with the highest number of publications. It is known that China and South Korea are the two countries with the highest number of publications in the field of Metaverse in Education (MVE). China recorded 37 publications, followed by South Korea with 24 publications. China obtained a total of 262 citations, while South Korea reached 420 citations, indicating the greater influence of these countries in the MV field.

Table 1 Countries with the highest number of documents and citations

Country	Frequency	Total Citations	Total Link Strength
China	37	262	27
South Korea	24	420	11
United Kingdom	11	115	8
Indonesia	10	32	13
Spain	9	129	9
India	8	95	11
United States	8	38	4
Malaysia	6	56	16
Turkey	5	94	10
Australia	5	14	3
Note: Only countries with more than 4 documents are included			

Table 2 shows the top affiliation in MVE publications, where the Smart Learning Institute of Beijing Normal University, Beijing, China, is at the top in scientific production (11) and total citations (91). This implies that this institution is a leading contributor to the field, producing high-quality research that is well-cited by other researchers. It is also interesting to note that several affiliations from Indonesia are on the list, indicating that this country has a strong presence in the field of metaverse in education. Jakarta State University and Universitas Negeri Padang are both among the most productive affiliations, with 7 and 6 documents, respectively. In terms of total link strength, the City

University of Ajman in the United Arab Emirates has the highest value, followed by Afyonkarahisar Health Sciences University in Turkey. This suggests that these institutions have strong collaborative networks and are well-connected within the research community.

Table 2 Countries with the highest number of documents and citations

Affiliation	Country	Documents	Citations	Total Link Strength
Smart Learning Institute of Beijing Normal University	China	11	91	10
Jakarta State University	Indonesia	7	14	2
University of Granada	Spain	7	15	3
City University of Ajman	United Arab Emirates	6	6	11
Universitas Negeri Padang	Indonesia	6	3	5
Afyonkarahisar Health Sciences University	Turkey	5	0	10
Beijing Language and Culture University	China	5	1	1
Wenzhou University	China	5	24	4
Note: Only institutions with more than 4 documents are included				

2. Researchers' Profile and Source Titles

2.1 Top Author

The author's profile yields essential information into the evolution of MVE research, including productivity, collaboration patterns, and research impact. Table 3 highlights eight prominent authors in the MVE literature. Notably, these authors tend to share a common trait – a relatively modest number of documents (3). This trend is attributed to their recent entry into the field, starting their publication journey in 2022.

Table 3 List of top authors and their impact on MVE research

Authors	Doc.	Citations	Total Link Strength
Zhao, J.	3	92	24
Aburayya, A.	3	19	19
Liu, Y.	3	2	9
López-Belmonte, J.	3	19	9
Moreno-Guerrero, A.J.	3	19	9
Pozo-Sánchez, S.	3	19	9
Yu, Z.	3	3	4
Hwang, Y.	3	55	3
Note: Only authors with more than 2 documents are included			

However, certain authors stand out due to their substantial total citation counts, indicating the recognition and impact of their contributions. Authors like Zhao, J., and Hwang, Y. have garnered significant attention within the scholarly community. Moreover, authors such as Liu, Y. and Yu, Z. have comparatively fewer citations but demonstrate strong link strength. This suggests that while their individual works might not be heavily cited, they contribute to a well-connected scholarly

network, fostering collaboration and knowledge dissemination. The collaborative trio of López-Belmonte, J., Moreno-Guerrero, A.J., and Pozo-Sánchez, S. stands out for their shared metrics, including documents authored, total citations, and total link strength.

2.1 Top Sources

The most influential sources are shown in Table 4. The number of publications (N) by each source varies, with some having a higher frequency than others. "IEEE Transactions on Learning Technologies" has the most publications (9), followed by "Sustainability" (5). The variation in publication frequency can indicate the source's commitment to disseminating research in the field. Nevertheless, "IEEE Transactions on Learning Technologies" records a total link strength of 0, implying limited network connections. Meanwhile, "Frontiers in Psychology" and "Interactive Learning Environments" have notably high link strengths, indicating robust engagement with other researchers and publications in the field.. The number of citations received by each source reflects their recognition and influence within the broader research community. "Sustainability" leads with 114 citations, demonstrating its significant contribution to MVE literature. In contrast, sources like "Education and Information Technologies" and "International Journal of Information and Education Technology" have received fewer citations, but their Cite Scores suggest a focused and impactful presence. The collaborative and multidisciplinary nature of MVE research is underscored by the network engagement and interaction among these sources, ultimately contributing to the evolution and advancement of the field.

Table 4 Top Sources

Sources Name	N	Citations	Total Link Strength	Cite Score
IEEE Transactions on Learning Technologies	9	11	0	8.5
Sustainability	5	114	59	5.8
Frontiers in Psychology	4	68	101	4.5
Electronics	4	100	62	4.7
Interactive Learning Environments	3	76	87	11.0
Heliyon	3	27	55	5.6
Education and Information Technologies	3	5	51	8.2
Note: Only sources with more than 2 documents are included				

For the Sustainability source, "Identifying World Types to Deliver Gameful Experiences for Sustainable Learning in the Metaverse" become the article with the most citations (54 citations). The authors discuss the potential of the metaverse to turn imagination into reality through the convergence of various technologies and should be considered as a medium for sustainable education, free from the constraints of time and space. Witnesses the results of bibliographic coupling analysis for different types of sources, which can be categorized into three main clusters of MVE sources:

(i) The first cluster, depicted in red nodes (n = 37), includes key sources like Sustainability, Interactive Learning Environments, Heliyon, and Applied Sciences.

(ii) The second cluster, represented by green nodes (n = 20), comprises notable sources such as Education and Information Technology, IEEE Access, and Interactive Technology and Smart Education.

(iii) The third cluster, indicated by blue nodes (n = 14), features essential sources like Electronics, Computers and Education, and International Journal of Information and Communication Technology Education.

While not all sources are directly related to education, the majority of MVE sources are interconnected. This observation aligns with the findings in Table 4, where most top sources are

associated with the educational context. Nevertheless, if analyzed comprehensively, the dataset includes sources from various disciplines, such as psychology, education, technology, and health. This diversity highlights the multidisciplinary nature of MVE research, where insights from different fields converge to explore the metaverse's impact on education.

3. Most Influential Literature

Table 5 presents the list of highly cited articles in the field of MVE research, which have significantly influenced subsequent research and inspired further exploration of this intriguing and multidimensional subject.

Table 5 Most highly cited MVE work

Rank	Citation	Author(s)	Source
1	116	[28]	Computers and Education: Artificial Intelligence
2	96	[20]	Smart Learning Environments
3	60	[29]	Electronics
4	60	[30]	Interactive Learning Environments
5	54	[31]	Sustainability
6	51	[32]	Journal of Intelligence
7	51	[33]	Applied Sciences
8	45	[34]	Sustainability
9	44	[35]	Journal of Educational Evaluation for Health Professions
10	41	[36]	Frontiers in Psychology

These highly cited articles collectively provide a comprehensive understanding of various aspects of MVE, ranging from technology and interventions to their impact on the learning environment and learning experience.

4. Keywords Trend and Thematic Analysis

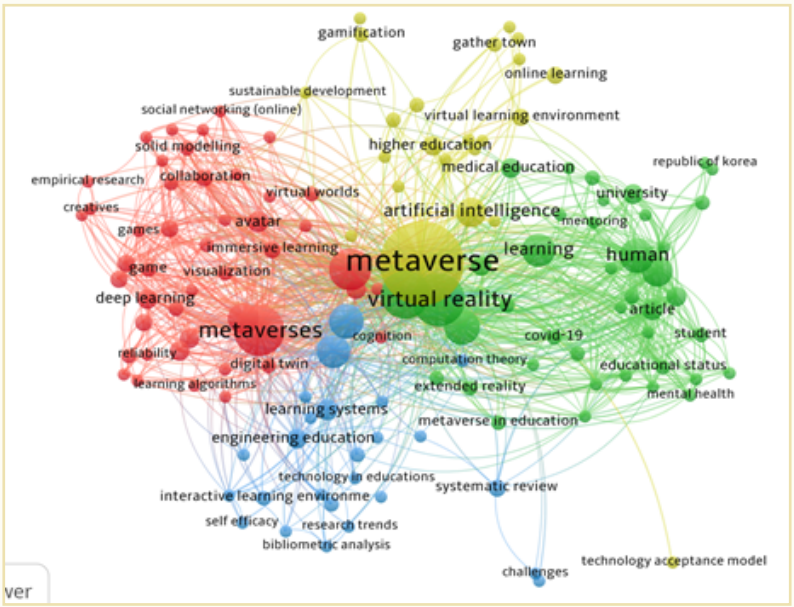

Figure 2 Co-occurrence network analysis

Table 6 Thematic analysis of keyword co-occurrences

Main Theme (Color)	Sub-theme	Description	Nodes Example
Educational Technology and Pedagogy (Red)	Educational Technology	This cluster emphasizes the role of technology in education, shaping the educational experience within metaverses. Also, it suggests a strong interest in leveraging technology for effective teaching and learning.	E-learning, deep learning, educational games, avatars
	Learning Theory	Some theoretical bases indicate a focus on how learners actively construct knowledge in metaverse-based educational settings. This theme suggests a deep interest in understanding the cognitive processes involved.	Constructivism, cognition, social aspects
Immersive Learning Environments and Research Method (Green)	Immersive Technologies	The cluster prominently features keywords related to various immersive technologies, such as virtual, augmented, and mixed reality. This indicates a strong interest in creating immersive educational experiences.	Virtual reality, augmented reality, and mixed reality
	Student-centered Learning	Learning is focused on the student experience in metaverse-based education. Researchers are likely exploring how these technologies enhance learning outcomes, engagement, and self-efficacy. The occurrence of a problem-based learning model also supports the application of student-centered learning.	Student, university, nursing student, self-efficacy, problem-based learning
	Research Method	Previous researchers used quantitative methods with questionnaire instruments, which were associated with immersive technologies, metaverse, and learning.	Quantitative analysis, questionnaire
Educational Evaluation and Research (Blue)	Interactive Learning	MVE may imply a focus on creating dynamic and engaging metaverse-based educational settings. Researchers may be exploring how interactivity influences learning outcomes.	Interactive learning environments, learning outcome
	Teacher Involvement	"Teachers" as a keyword suggests recognizing the crucial role educators play in metaverse-based education. Researchers may be investigating strategies for teacher training and development.	Teachers, teaching, personnel training
	Educational Research	This cluster strongly emphasizes research methodologies, systematic reviews, bibliometric analyses, and research trends. It suggests a commitment to rigorous and evidence-based inquiry within MVE research.	Systematic reviews, bibliometric analyses, PRISMA
Metaverse, Technology Integration, and Sustainability (Yellow)	Metaverse and Technology	This cluster highlights the integration of metaverse technologies, like artificial intelligence, virtual learning, and gamification, into educational contexts. It suggests a focus on how advanced technologies can enhance the learning experience.	Artificial intelligence, gamification, learning experience
	Attitudes and Acceptance	The presence of "attitude" and "TAM" suggests an interest in understanding how individuals perceive and adopt metaverse technologies for educational purposes.	Attitude, TAM, perception
	Sustainability	The correlation between metaverse and Education for Sustainable Development (ESD) indicates an awareness of environmental and ethical considerations in MVE. Researchers may be exploring ways to make metaverse-based education more sustainable. Additionally, it also means that MVE may actualize ESD achievement.	Sustainability, sustainable development

DISCUSSION

The results of this study confirm that China and South Korea lead in the number of publications and citations in the field of MVE. This finding is in line with the opinions of [37; 38], which state that these two countries are the main pioneers in the development of MVE in education. The data we obtained is consistent with the opinion of Chen et al. [7] who also identified China and South Korea as productive MVE research centers in the Web of Science database, with China dominating in terms of publication quantity, while South Korea is superior in citations. These findings suggest that these countries have infrastructure and educational policies that support advancements in metaverse-based educational technologies.

In terms of researcher profiles, our findings show that authors such as Zhao, J. and Hwang, Y. have major contributions despite their limited number of publications. We agree with the opinion of Hwang & Chien [28] who mentioned that authors with a small number of publications but with high citations often show significant impact in the development of research. Therefore, even though they are new to this research, their contributions are valuable to deepen our understanding of MVE. On the other hand, the IEEE Transactions on Learning Technologies journal with the highest number of publications but low link strength, shows minimal connectedness with other scientific networks.

Most of these articles used quantitative methods, while some also utilized qualitative ones. The top rank is occupied by Hwang & Chien, who intended to give researchers from the fields of both computer science and educational technology a clear picture of what the metaverse is and how it can be used for educational purposes. Following that, Tlili et al. (2022) conducted a content and bibliometric analysis, revealing the design of MVE has evolved over generations, where Generation Z is more targeted with artificial intelligence technologies compared to Generation X or Y. In the third position, Jovanović & Milosavljević (2022) introduced a novel platform, “VoRtex” that provides assistive tools for building an educational experience in virtual worlds and overcoming the boundaries caused by pandemic situations. Meanwhile, Rospigliosi (2022) secured fourth place by exploring why MVE's turn to the virtual is worth considering and how it presents new and highly flexible opportunities for learning environments and learning experiences that mirror changes to how we socialize and work. Subsequently, [31] examined the relationship between gameful experience and learning motivation by analyzing previous studies. Furthermore, the works of [38-40] have also significantly contributed to the advancement of MVE research. Their tremendous impact on the subject has set the path for additional research and innovation, eventually promoting the growth of MVE as an essential area of educational technology study [39].

The findings regarding keyword trends show that the most discussed topics are Metaverse, Virtual Reality (VR), and Metaverses, indicating the dominance of immersive technologies in the development of metaverse-based education. In line with research by [40] who said that technologies such as VR and AR have great potential in creating more engaging and interactive learning experiences. The data we obtained is consistent with the opinion of [41] which states that MVE has great potential to transform the educational environment, by providing a more active and constructivism-based student-centered learning experience.

The metaverse is becoming increasingly important in education due to its potential to provide immersive and interactive learning experiences that can enhance learning and teaching experiences. This interactivity allows students to interact with the educational content, simulations, or virtual environments in real-time, enabling them to manipulate objects, explore scenarios, and receive immediate feedback based on their actions [42]. Moreover, The metaverse's gamified elements and interactive features make learning engaging and enjoyable [43]. This heightened engagement fosters intrinsic motivation and positive learning outcomes [31]. ‘Roblox’ Metaverse can improve students non-cognition abilities, including learning motivation and engagement [44]. Besides Roblox, another metaverse platform like Zepetto positively predicted users’ perception of social self-efficacy [45].

Empirical evidence also substantiates the claim that the metaverse can significantly enhance student interaction and improve learning outcomes. For instance, two prominent metaverse platforms, Second Life and Solipsis, have demonstrated their ability to enhance multilingual interactions and, consequently, augment language learning outcomes [46]. Additionally, research has shown that the metaverse can be a catalyst for improving Korean language education outcomes through enhanced interactions [47]. Beyond language learning, the metaverse exhibits the potential

to positively impact student learning outcomes in various academic domains, including the sciences [5]. These immersive environments offer unique opportunities for learners to engage, collaborate, and acquire knowledge, ultimately leading to improved educational outcomes [7].

The use of the metaverse also increases learner engagement through student-centered learning, which emphasizes that learners construct their own knowledge through social interaction and active participation in the learning process. The metaverse provides a platform for constructivist learning strategies such as situational learning, cognitive apprenticeship, and social negotiation [32]. The use of the metaverse in education can also promote collaboration and social interaction among learners [8], which is a key aspect of social constructivist learning theory by Vygotsky [48]. In addition to pupils, teachers also have an important role in implementing metaverse-based learning. They may guide students on how to use the metaverse effectively and safely. This can include setting expectations for behavior and providing guidelines for appropriate use [49]. Ultimately, the effectiveness of using metaverse in the classroom can be evaluated by teachers to monitor student progress and engagement, identify areas for improvement, and make adjustments to their teaching practices [1].

The thematic results of the previous analysis also suggest a strong connection between the MVE and ESD. This relationship can be elucidated by the way the metaverse transcends geographical boundaries, fostering global connections among students and educators from diverse backgrounds. This interconnectedness nurtures a profound sense of global awareness and responsibility, which is at the core of ESD principles. It offers virtual field trips to ecologically significant locations, as demonstrated in the research by [50]. Such experiences are pivotal in deepening students' comprehension of environmental issues and their roles in conservation efforts. While it's true that the scientific literature on the metaverse has not yet extensively delved into global and local sustainability topics [51], there are abundant opportunities on the horizon. Therefore, exploring sustainability within the metaverse offers the potential for meaningful contributions to addressing global and local sustainability challenges.

CONCLUSION AND IMPLICATIONS

This study implies for some parties. For educators, they can create innovative lessons on environmental topics – related to ESD, such as climate change and biodiversity conservation. These experiences can significantly deepen students' understanding as well as actualize ESD. Additionally, educators can enhance their curricula by incorporating metaverse-based activities, improving the quality of teaching and learning through the intervention of recent emerging technology. Ultimately, future researchers may explore the multifaceted aspects of MVE, contributing a deeper understanding of the metaverse's impact. Recognizing the long-term impact of metaverse-based initiatives on education is also crucial. Researchers should adopt a longitudinal approach to studying these effects. The limitation of this study is that it focuses only on the Scopus database, so it is worth considering other databases, such as Google Scholar or Web of Science, that may have broader insight into MVE literature. Metaverse and educational technologies are rapidly evolving, so newer trends and publications might not be included. For the remedy, future studies should complement this research with other aforementioned databases. If possible, deepening MVE literature content analysis through systematic review or meta-analysis can gain a more comprehensive understanding of this topic. Lastly, longitudinal studies tracking the evolution and long-term effects of metaverse initiatives in education can provide valuable insights into their sustained impact.

ACKNOWLEDGEMENT

The author’s gratitude goes to LPPM, Universitas Negeri Surabaya, Indonesia for supporting this research and publication.

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The author's declared no conflicts of interest