Journal of Infrastructure, Policy and Development 2024, 8(13), 8984.
https://doi.org/10.24294/jipd8984

Review

Reexamining metaverse with quantative scientometric approach

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CITATION

Jin X, Zhang S, Che S, et al. (2024). Reexamining metaverse with quantative scientometric approach. Journal of Infrastructure, Policy and Development. 8(13): 8984. https://doi.org/10.24294/jipd8984

ARTICLE INFO

Received: 4 September 2024
Accepted: 27 September 2024
Available online: 8 November 2024

Abstract: In recent years, the rapid development of technologies such as virtual reality, augmented reality, and mixed reality, along with the significant increase in publications related to the Metaverse, demonstrates a sustained growth in interest in this field. Some scholars have already performed bibliometric analyses of this emerging field. However, previous analyses have not been comprehensive due to limitations such as the volume of literature, particularly lacking in co-citation analysis, which is crucial for understanding the interconnectedness and impact of research works. In this study, we used the Web of Science as a database to search for topics related to the Metaverse from 1995 to 2023. Subsequently, we employed CiteSpace for co-citation network analysis to supplement previous research. Through our analysis at the journal, author, and literature levels, we identified core journals and key authors in the Metaverse field. We discovered that Extended Reality (XR), education, user privacy, and terminologies related to the Metaverse are significant research themes within the field. This study provides clear and actionable research directions for future papers in the Metaverse field.

Keywords: metaverse; co-citation analysis; CiteSpace; web of science (WOS); cluster analysis

1. Introduction

The concept of the Metaverse has been in existence for several decades since its inception in 1992, and it has gained popularity in science fiction literature and films (Stephenson, 1994). With the development of technologies like virtual reality (VR), augmented reality (AR), mixed reality (MR), and extended reality (XR), the Metaverse has become more feasible and realistic. Metaverse is a persistent multiuser environment that blends physical reality with digital virtuality (Mystakidis, 2022). It is an amalgam of today's online social experiences, projecting onto the physical world and allowing users to do things that they cannot do in the real world. The three-dimensional interactive nature between virtual and real environment created by the Metaverse enables social, economic, and cultural activities and creates value (Kye et al., 2021). Companies such as Facebook, Epic Games, and Roblox are investing heavily in the development of the Metaverse and many experts believe that it is only a matter of time before it becomes a reality (Higgins, 2022; Samantha Murphy Kelly, 2021).

With the focus of many industry giants and scholars, the Metaverse has already demonstrated substantial influence across various domains, such as the gaming industry (Kim, 2021). The gaming industry is one of the most prominent areas in which the Metaverse thrives. Fortnite, developed by Epic Games from 2017, is a prime example of a large-scale cross-platform multiplayer online game and is one of the most

renowned Metaverse games to date. Players can engage in exploration, socialization, combat, building, and various other activities within the game. Furthermore, Epic Games have organized numerous grand events within Fortnite, including collaborations such as the large-scale concert featuring Travis Scott (Duan et al., 2021). Additionally, in November 2021, the Seoul Metropolitan Government in South Korea unveiled the "Seoul Metaverse Five-Year Plan," outlining a three-phase strategy starting from 2022 to establish an administrative service ecosystem for the Metaverse, particularly in sectors like culture and education. Presently, many social (Buana, 2023; Oh et al., 2023), cultural (George et al., 2021; Han, 2020; Shen, 2022), and economic activities (Hamilton, 2022; Huang et al., 2022; Kshetri, 2022; Vidal-Tomás, 2023) are gradually transitioning toward Metaverse platforms, heralding substantial changes in people's work, learning, entertainment, and other aspects of life (Kye et al., 2021).

In the pursuit of identifying the hot research topics and future directions in the field of the Metaverse, several scholars (Damar, 2021; Nan et al., 2023; Shen et al., 2023; Tlili et al., 2022) have conducted bibliometric analyses. Damar (2021) conducted a comprehensive bibliometric analysis using precise keywords. However, it is crucial to acknowledge that the initial body of literature concerning the Metaverse remains considerably restricted, as indicated by their analysis encompassing 93 papers. Furthermore, Tlili et al. (2022) conducted a bibliometric analysis of Metaverse literature, but their focus was exclusively on the application of the Metaverse in the field of education. They argue that the implementation of the Metaverse can expand educational opportunities by exploring environments historically inaccessible due to spatial, temporal, and cost barriers, thus addressing real-world issues within virtual realms. While this research contributes to the advancement of the Metaverse, it remains confined to the educational realm and may not sufficiently support the overall development of the Metaverse field. Moreover, the literature data from Shen et al. (2023), are particularly comprehensive. In their study, in addition to using the term "Metaverse," they employed keywords such as "3D modeling" and "5G network" to retrieve relevant literature. This approach aims to expand the coverage of literature, obtain a greater number of data samples, and address the limitation of insufficient early research data. However, when using certain keywords (such as "deep learning"), the search results might include literature not only from the Metaverse field but also from domains like artificial intelligence or medicine. We suspect that the extensive use of such keywords could introduce information bias, potentially leading to less accurate research findings. Additionally, amidst the rapid proliferation of literature in the Metaverse field, Nan et al. (2023) conducted a bibliometric analysis of Metaverse research up until 2022 using the Web of Science (WOS) database. However, their study solely relied on citation analysis and did not incorporate co-citation analysis.

Compared to previous studies, the innovation of this research is reflected in the following aspects: First, we used a more comprehensive dataset, ensuring greater coverage in the analysis. Additionally, this study employed co-citation analysis. Co-citation analysis is a method that reveals the intrinsic connections between different pieces of literature by examining the frequency with which two papers are cited together by a third paper. Unlike conventional bibliometric analysis, co-citation analysis not only identifies key papers and influential authors in a field but also helps construct the knowledge structure of the field, uncovering the evolution and trends of

research themes (Gmür, 2003; Zhang et al., 2022; Zhao et al., 2023). Therefore, co-citation analysis is uniquely valuable in deeply exploring the knowledge landscape of a discipline and understanding the relationships between research themes.

Based on this, our study conducted a co-citation analysis of literature related to the Metaverse. Specifically, we carried out co-citation analysis at three levels. First, at the journal and author levels, we identified core journals and key authors with high co-citation frequencies in the Metaverse research field. Second, at the literature level, we integrated cluster analysis to explore important research themes and their interconnections within the field.

The primary objectives of this study are to comprehensively identify the most influential journals, authors, and key literature within the field of the Metaverse. By conducting a thorough co-citation analysis, we aim to pinpoint the scholarly works and individuals that have made the greatest impact on this emerging domain. Additionally, this research seeks to uncover the prominent and emerging research topics that are currently shaping the Metaverse landscape, providing a deeper understanding of the field's evolving trends and guiding future research directions.

2. Materials and methods

This study employs bibliometric methods to systematically explore scientific literature related to the Metaverse, aiming to reveal the main research trends, core themes, and influential authors and works within the field through quantitative analysis. The data extraction and analysis processes are described as follows.

2.1. Data extraction

WOS was the inaugural comprehensive international bibliographic database and remains the foremost influential data source for research assessment and bibliometric analysis (Li et al., 2018; Pranckutė, 2021). Therefore, in this study, we used WOS as the data source for Metaverse-related literature. The data extraction process is presented in **Table 1**.

Table 1. Data extraction process.

Data source	**SCI-EXPANDED, SSCI, CPCI-SSH, CPCI-S, ESCI, A&HCI of the WOSCC databases**
Search query	Topic = "Metaverse*"
Selection criteria	Document type: "Article" or "Proceeding Paper" or "Early Access" or "Review Article"
	Document language: "English"
	Publication Date: 1995-01-01/2023-03-31
Retrieved time	2023.04.17
Number of results	908

We screened the data sources from the literature provided by WOS. The Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI), Conference Proceedings Citation Index–Social Science and Humanities (CPCI-SSH), Conference Proceedings Citation Index–Science (CPCI-S), Emerging Sources

Citation Index (ESCI), and Arts and Humanities Citation Index (A&HCI) provided by the Web of Science Core Collection were used as data sources. Then, regarding search query, we used the keyword "Metaverse*" to retrieve the data.

Regarding the selection criteria, we selected items classified as "Article," "Proceeding Paper," "Early Access," or "Review Article." The document language was limited to English. Literature published on WOS between 1 January 1995 and 31 March 2023 were retrieved, and 908 articles were obtained as the data for this study.

2.2. Data analysis and analysis tools

Commonly used bibliometric tools include VOSviewer, Gephi, SATI, HistCite, and RefViz. These software programs have their own advantages, but also have certain limitations. SATI cannot draw a timeline, HisCite relies heavily on word frequency analysis, and ReViz is mainly used for keyword group analysis (Wang et al., 2021). CiteSpace is currently the most comprehensive bibliometric tool available (Che et al., 2022).

3. Results and discussion

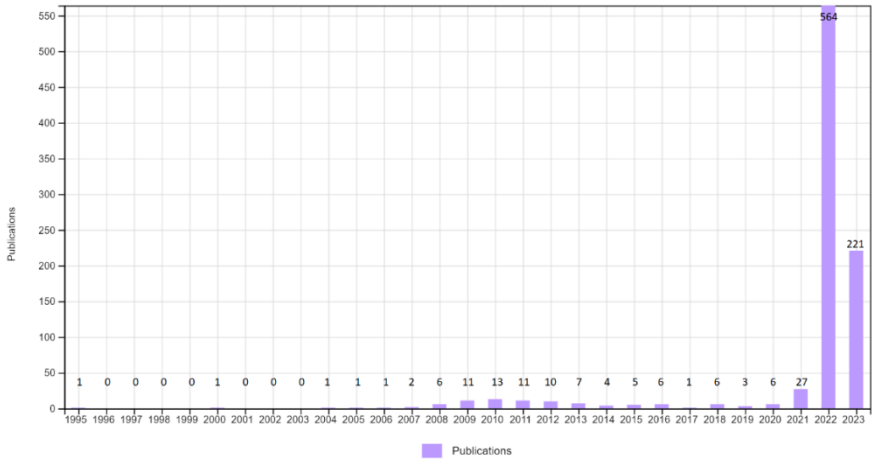

Figure 1. Publications over time.

In our analysis, we utilized the tools provided by the Web of Science (WOS) to retrieve relevant literature through the "Metaverse*" keyword search. The findings are presented in **Figure 1**, which clearly illustrates the explosive growth of Metaverse-related literature in 2022. This growth has consequently influenced the results of bibliometric analyses conducted on the Metaverse field prior to and following that year. Therefore, this also makes the results of the analysis in this study more convincing compared to the previous bibliometric literature.

Co-citation analysis is a widely used method to investigate knowledge frameworks in a particular academic field (Chen and Liu, 2020; Sun et al., 2022; Zhao et al., 2023). This study used CiteSpace to analyze journal co-citation networks, author co-citation networks, and literature co-citation networks. Nodes with a high co-citation frequency usually have a strong influence in the field and are considered important in node networks. Based on the experience provided by previous bibliometric literature, we used co-citation frequency as the evaluation index to rank the nodes (Zhang et al.,

2022; Zhao et al., 2023). The top ten most-cited nodes in each network were extracted and entered into a table for analysis.

3.1. Journal co-citation analysis

Table 2. Journal co-citation count.

Rank	Cited Counts	Journal
1	233	IEEE ACCESS
2	223	ARXIV
3	145	LECTURE NOTES IN COMPUTER SCIENCE
4	131	SENSORS-BASEL
5	127	COMPUTERS IN HUMAN BEHAVIOR
6	125	APPLIED SCIENCES-BASEL
7	120	ACM COMPUTING SURVEYS
8	109	INTERNATIONAL JOURNAL OF INFORMATION MANAGEMENT
9	109	SUSTAINABILITY-BASEL
10	91	COMPUTERS & EDUCATION

Clustering of the journal co-citation network is shown in **Figure 2**. In **Figure 2**, each node represents a journal, with larger nodes indicating higher citation counts of papers within that journal. The presence of links between nodes signifies a co-citation relationship between the two journals. We sorted all nodes by co-citation frequency and screened the top 10 nodes to obtain the journal co-citation count (**Table 2**). Among these, the top two nodes, IEEE Access (233) and ARXIV (223), had co-citation frequencies of more than 200, far exceeding those of other journals. This indicates that these two nodes have a greater influence than the other nodes in the journal co-citation network.

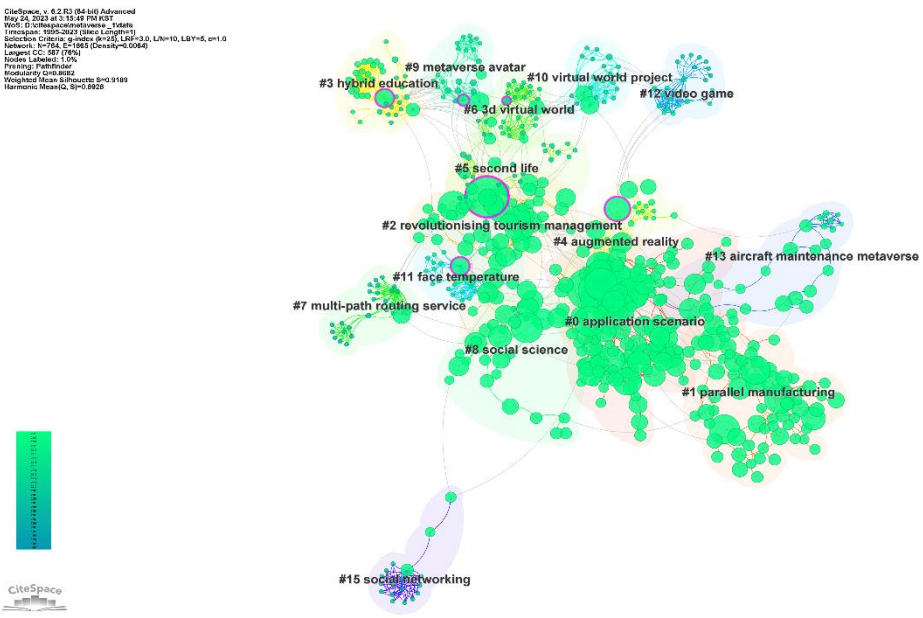

Figure 2. Journal co-citation network.

3.2. Author co-citation analysis

Table 3. Author co-citation count.

Rank	Cited Counts	Author
1	101	Neal Stephenson
2	98	Sang-Min Park
3	95	Stylianos Mystakidis
4	93	Lik-Hang Lee
5	82	John David N. Dionisio
6	53	Huansheng Ning
7	53	Haihan Duan
8	51	Jooyoung Kim
9	48	Hyeonju Lee
10	48	Yogesh K. Dwivedi

Author co-citations can identify authors engaged in research in a certain field and evaluate their influence and research direction. Clustering of the author co-citation network is shown in **Figure 3**. In **Figure 3**, each node represents an author, with the size of the node indicating the frequency of citations for that author. The links between nodes represent a co-citation relationship among the authors. This relationship indicates a certain degree of correlation or close connection between the research of these authors. In this node network, we sorted authors according to co-citation frequency, excluding anonymous authors (**Table 3**). As shown in **Table 3** the citation frequency of the top four authors was significantly higher than that of the top five–ten authors. Among them, Stephenson N (101) was cited far more frequently than the other authors. His main contribution was the first use and definition of the term Metaverse in his 1992 novel Snow Crash. The second-ranked author Park SM (98), third-ranked author Mystakidis S (95), and fourth-ranked author Lee LH (93) were in the same cluster. Their research focused on application scenarios. From the perspective of co-citation frequency, we believe that these four authors were highly influential in the Metaverse field.

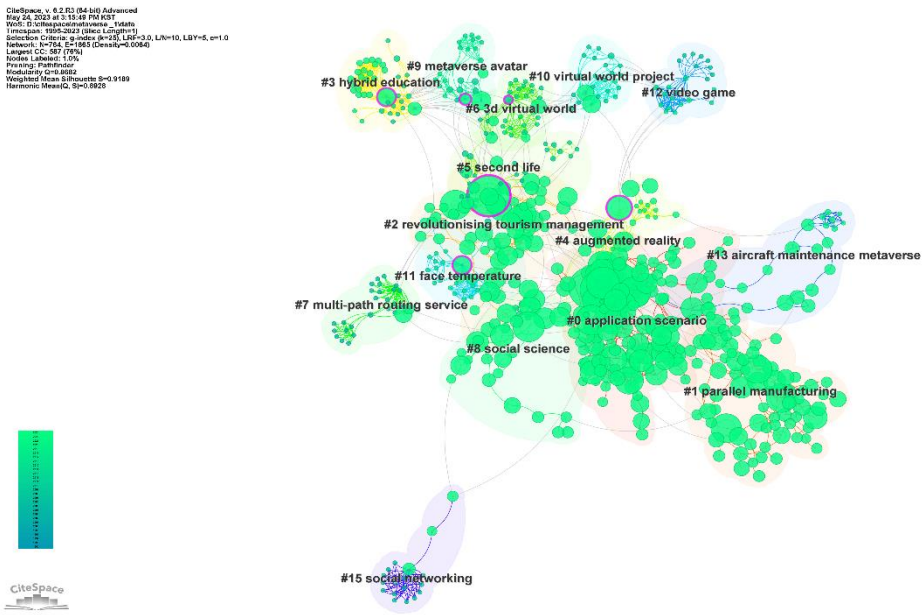

Figure 3. Author co-citation network.

3.3. Literature co-citation-based cluster analysis

We conducted a cluster analysis of the literature co-citation network, resulting in five clusters (**Figure 4**). In **Figure 4**, each cluster represents a group of interconnected nodes. Each node represents a document, with the node size indicating the frequency of citations for that document. Nodes within the same cluster share similar citation relationships, indicating common research themes among them. The titles of the clusters represent the general research direction of the documents within that cluster. The silhouette coefficients of these clusters were all greater than 0.8, indicating that they had high homogeneity and were convincing (Chen et al., 2014). Because the clustering labels obtained using the log-likelihood ratio (LLR) are confusing, we used latent semantic indexing (LSI) to generate clustering labels. This technique has been shown to capture key relational information, including causal, goal-oriented, and categorical information (Graesser et al., 2000). Finally, the main theme of each cluster was explained using the major citing article in each cluster.

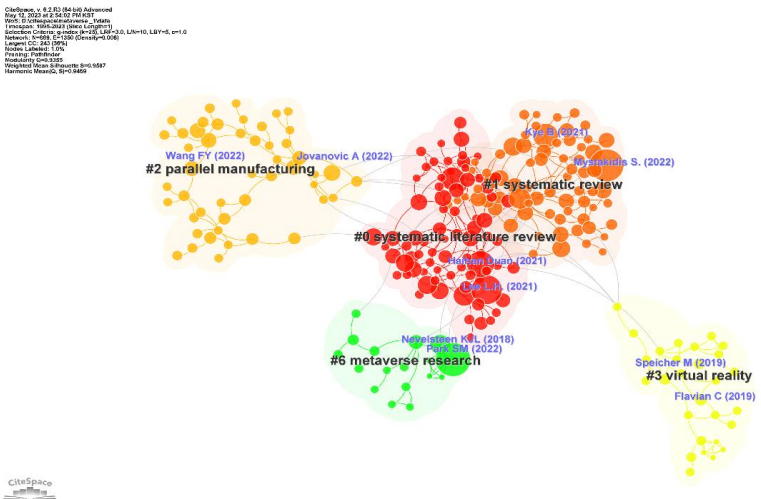

Figure 4. Literature co-citation network.

Cluster 0, as the largest cluster, consists of 79 members, and its theme is "systematic literature review". The major citing article of the cluster is a review article that summarizes the relevant literature on the Metaverse (Al-Ghaili et al., 2022). This cluster reports the challenges faced by researchers in the Metaverse field and provides insights into future development trends.

Cluster 1 has 70 members and its theme is "systematic review." The most cited article in this cluster focused on the application of the Metaverse in healthcare from a healthcare perspective (Chengoden et al., 2023). The theme of this cluster is similar to that of Cluster 0, but the content is different. The main objective of Cluster 1 was to provide specific research and introductions to Metaverse-related technologies.

Cluster 2 consists of 48 members and is labeled as "parallel manufacturing." Parallel manufacturing is an emerging manufacturing model based on cyber-physical social systems (CPSS). It employs the "Artificial Systems," "Computational Experiments," and "Parallel Execution" (ACP) approach to bridge the modeling gap between actual manufacturing systems and their models caused by complex human and social behaviors (Yang et al., 2022). The major citing article in this cluster investigates and introduces parallel manufacturing and its related concepts (Zhao et al., 2022).

Cluster 3 has 28 members, and its theme is "virtual reality." There have been inconsistencies in the use of terms related to VR in the academic community and among professionals, leading to confusion in subsequent studies. However, the major citing article in this cluster provided explanations of these terms, aiming to clarify the meanings of VR-related terminology (Rauschnabel et al., 2022).

Cluster 6 consists of 18 members and is labeled as "Metaverse research." This cluster primarily focuses on literature related to Metaverse fields. The major citing article in this cluster is a paper written using bibliometric methods that considered national contributions, institutional contributions, and keywords (Shen et al., 2023). The purpose of this cluster was to analyze the level of scholarly interest and contributions to the Metaverse field by researchers worldwide.

Among these clusters, the most prominent one is Cluster #0, with a significantly larger number of members compared to other clusters. This indicates that, from the perspective of cluster analysis, the Metaverse field is primarily concerned with comprehensive summaries rather than focusing on specific technologies or application areas.

3.4. Literature co-citation analysis

Table 4. Literature co-citation count.

Rank	Cited Counts	References
1	94	Park and Kim (2022)
2	87	Mystakidis (2022)
3	71	Lee et al. (2021)
4	53	Duan et al. (2021)
5	44	Kye et al. (2021)
6	40	Dwivedi et al. (2022)

Table 4. (*Continued*).

Rank	Cited Counts	References
7	35	Falchuk et al. (2018)
8	32	Ning et al. (2023)
9	28	Nevelsteen (2018)
10	27	Xi et al. (2023)

In the literature co-citation network, we ranked the nodes based on their co-citation frequency as research indicators and selected the top 10 nodes to compile **Table 4**. To understand the main research hotspots of the literature in the Metaverse field up to now, we summarized the research content of these papers. Among the 10 papers, there are 4 comprehensive literature reviews that cover a wide range of topics (Dwivedi et al., 2022; Lee et al., 2021; Ning et al., 2023; Park and Kim, 2022). Therefore, when summarizing the content, we merged the topics covered in these papers with the research themes of other literature. The final results are as follows:

First, XR is a prominent research topic in the Metaverse field. Xi et al. (2023) summarized a study on the impact of XR on workload. Additionally, XR is addressed in 4 articles by Park and Kim (2022), Dwivedi et al. (2022), Lee et al. (2021), and Mystakidis (2022). They describe XR as a broad term that encompasses VR, AR, and MR. XR systems employ various multimodal devices like stereoscopic displays, audio, and motion controllers to create a rich and immersive virtual universe, enabling users to actively engage with virtual objects through touch, manipulation, and operation (Lee et al., 2021; Mystakidis, 2022; Park and Kim, 2022). Xi et al. (2023) show that the use of AR significantly increases workload in retail environments, particularly in terms of psychological demands and effort. In contrast, VR does not significantly impact workload. Interestingly, combining AR and VR technologies does not escalate task complexity compared to using either technology individually, and it may even reduce certain challenges, such as physical demands. These findings offer valuable insights for XR designers and developers in effectively managing workload. Furthermore, Dwivedi et al. (2022) delve into the relationship between XR and the Metaverse, conceptualizing the Metaverse as a fully immersive 3D environment that seamlessly integrates the physical and virtual realms, accessible through XR interfaces. The author underscores XR's significance as a key technology for realizing the Metaverse, with AR and VR playing pivotal roles within the XR framework. Overall, these studies elucidate the definition, characteristics, and application domains of XR technology.

Second, the application of the Metaverse in the field of education garnered substantial interest from numerous scholars. Mystakidis (2022) and Kye et al. (2021) have conducted research on the application of the Metaverse in the context of re-education. Additionally, the works of Park and Kim (2022), Dwivedi et al. (2022), Ning et al. (2023), and Duan et al. (2021) also contain sections relevant to education. Mystakidis (2022) points out that simulations and gaming experiences in virtual reality offer learners opportunities to apply theoretical knowledge, conduct experiments using devices, engage in complex programming exercises, cultivate behavioral skills, and learn from mistakes without considering the consequences or severity in the physical

world. Kye et al. (2021) is a literature review specifically focused on the field of education, elucidating the characteristics of four types of Metaverse, the potential of educational applications, the convergence and complexity of Metaverse types, as well as the potential and limitations of Metaverse in educational settings. Additionally, the other four papers also provide valuable insights, to varying degrees, into the advantages of Metaverse applications in education compared to traditional teaching methods involving textbooks. It is noteworthy that among the top 10 ranked papers, over half of them (6 papers) delve into the application of the Metaverse in education. We believe that education stands as the top-ranked hotspot topic in Metaverse-related research.

Third, privacy is also one of the hot topics in the field. Falchuk et al. (2018) have conducted research on privacy issues related to the Metaverse. Lee et al. (2021) and Dwivedi et al. (2022) also mention privacy-related matters. Falchuk et al. (2018) discussed privacy breaches and potential solutions that users face when participating in the Metaverse. The Metaverse possesses high levels of openness, numerous virtual characters, and a diverse community of anonymous users. These characteristics might lead to malicious tracking and surveillance of users' personal information. Leaks of personal information may result in harassment and deceit targeted at user avatars. However, not collecting user data could weaken the innovation potential of the Metaverse ecosystem (Falchuk et al., 2018; Lee et al., 2021). Currently, there is not a perfect solution to this challenge. A novel approach is the implementation of privacy transactions with user consent, allowing users to exchange personal data for benefits (Acquisti et al., 2016).

Fourth, Nevelsteen (2018) employed grounded theory to sample technology, resulting in a detailed definition of virtual worlds and encompassing definitions of all underlying components. This literature furnishes the research community with a comprehensive definition of virtual worlds that is sufficiently detailed and can be continually updated.

4. Discussion

This study systematically complements existing research in the Metaverse field through bibliometric methods, particularly co-citation analysis. By analyzing relevant literature published between 1995 and 2023 in the Web of Science database, we have identified the research hotspots, core journals, influential authors, and key research themes in this field.

Firstly, the relatively straightforward analysis includes 2 components: journals, and authors. At the journal level, IEEE Access and ARXIV have been identified as core journals in the Metaverse field because of their extremely high co-citation frequencies. This finding differs slightly from those of recent bibliometric studies in the Metaverse field. Shen et al. (2023) considered Lecture Notes in Computer Science to be a core journal in the field of the Metaverse because of its substantial contribution in terms of the number of published papers. The main reason for this difference is that the data collection for early published papers used a broader range of keywords or was conducted earlier, resulting in a smaller dataset. At the author level, Stephenson N,

Park SM, Mystakidis S, and Lee LH are considered important scholars in the field because of their high co-citation frequencies.

Besides, at the cluster level of literature analysis, Cluster #0 (systematic literature review) emerges as the most significant cluster, comprising 79 members. This implies that the majority of scholars in the Metaverse field are primarily focused not on technical aspects but rather on exploring the challenges faced in the development of the Metaverse. We view this as a process of risk identification and risk analysis. Within this process, scholars utilize past data or theoretical models to determine potential adverse impacts while also fostering imaginative thinking towards future possibilities (Valis and Koucky, 2009). The significance of this finding lies in highlighting a shift in the scholarly focus within the Metaverse field—from purely technical development to a more comprehensive research approach that encompasses socio-economic and regulatory challenges. By identifying this shift, our study contributes to a better understanding of the evolving research priorities in the Metaverse domain. It underscores the importance of addressing the risks and uncertainties that could hinder the growth and sustainability of the Metaverse. Moreover, our research not only advances the discussion on technical progress but also directs attention to the ethical, legal, and social implications of the Metaverse. This broader perspective is crucial for guiding policymakers, developers, and stakeholders, helping them better understand the potential challenges and impacts that may arise as the Metaverse evolves. Therefore, our findings contribute not only to academic literature but also hold practical value, promoting a more balanced and forward-looking discourse on the future of the Metaverse.

Moreover, at the literature level, the main related research topics identified included XR, education, user privacy, and terminology definitions. First, the research related to XR analyzes the role of technologies such as AR, VR, and MR in the Metaverse (Dwivedi et al., 2022; Lee et al., 2021; Mystakidis, 2022; Park and Kim, 2022). Furthermore, in the study of Xi et al. (2023), the impact of these technologies on workload was analyzed. Second, research in the field of education has focused on the application of the Metaverse in education. In this context, the discussion revolves around the cost-free trial-and-error opportunities that students gain through experiencing education via the Metaverse, as well as the advantages of this novel educational approach compared to traditional methods (Duan et al., 2021; Dwivedi et al., 2022; Mystakidis, 2022; Ning et al., 2023; Park and Kim, 2022). Research on the Metaverse in education has garnered substantial interest among scholars, with a significantly larger number of publications than on the other two topics. Third, from the perspective of user privacy, we identified potential privacy issues arising from Metaverse characteristics (Falchuk et al., 2018). Researchers have proposed many solutions to address this issue; however, no perfect solution has been found thus far. Finally, owing to the lack of universally accepted definitions in the virtual world domain, there have been ongoing controversies (Nevelsteen, 2018). The research topic of terminology definition has contributed to resolving this debate. Our research findings emphasize that the Metaverse field does not rely solely on a single discipline, but rather is a highly interdisciplinary research system. By integrating perspectives from technology, law, education, and ethics, sustainable development and innovative applications of the Metaverse can truly be advanced.

5. Limitations and future studies

This study researched literature in the Metaverse field from the perspective of co-citation analysis. It analyzed the node network of the data using co-citation frequency as evaluation metrics, thereby supplementing the existing bibliometric analysis of the Metaverse field. However, this study had certain limitations.

Although WOS is one of the most well-known literature databases, it still has certain limitations in terms of coverage and data completeness. This study relied solely on WOS as the data source, which may have resulted in the omission of relevant literature from other important databases (such as Scopus). Therefore, future research could consider integrating multiple databases to enhance the comprehensiveness and completeness of the analysis. Additionally, during the data collection process, the language of the documents was restricted to English, which may have overlooked relevant studies published in other languages. Thus, future research could incorporate multilingual literature analysis to provide a more holistic understanding of the development of the Metaverse across different countries and linguistic contexts. The data in this study is up to March 2023, which poses a temporal limitation, especially considering the rapid development of this field. This limitation implies that the results of this study may not fully capture the most recent dynamics and cutting-edge developments in the Metaverse field. Future research could include more updated data to better track the evolving trends and emerging hotspots in Metaverse research.

6. Conclusion

Based on the existing research in the field of the Metaverse, which has not yet conducted co-citation analysis, we aim to supplement this aspect. In our study, we employed four citation analysis methods (journal co-citation analysis, author co-citation analysis, literature co-citation analysis, and cluster analysis based on literature co-citation), utilizing co-citation frequency as the evaluation metric to analyze the existing literature in the Metaverse field.

From a theoretical perspective, we identified the current knowledge framework in the Metaverse field through co-citation analysis. By examining journals, authors, and literature, we constructed a clear node network. After identifying nodes with high co-citation frequencies, we gained insights into the most influential journals, authors, and research themes across these three levels. From a practical standpoint, our research provides valuable guidance for scholars looking to engage in Metaverse studies in the future, effectively assisting them in determining their research directions.

Funding: This work was supported by a National Research Foundation of Korea (NRF) grant funded by the Korean government (RS-2023-00208278).

Data availability statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of interest: The authors declare no conflict of interest.

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