What Do We Know About Metaverse? Insights for Future Studies Based on Bibliometric Analysis

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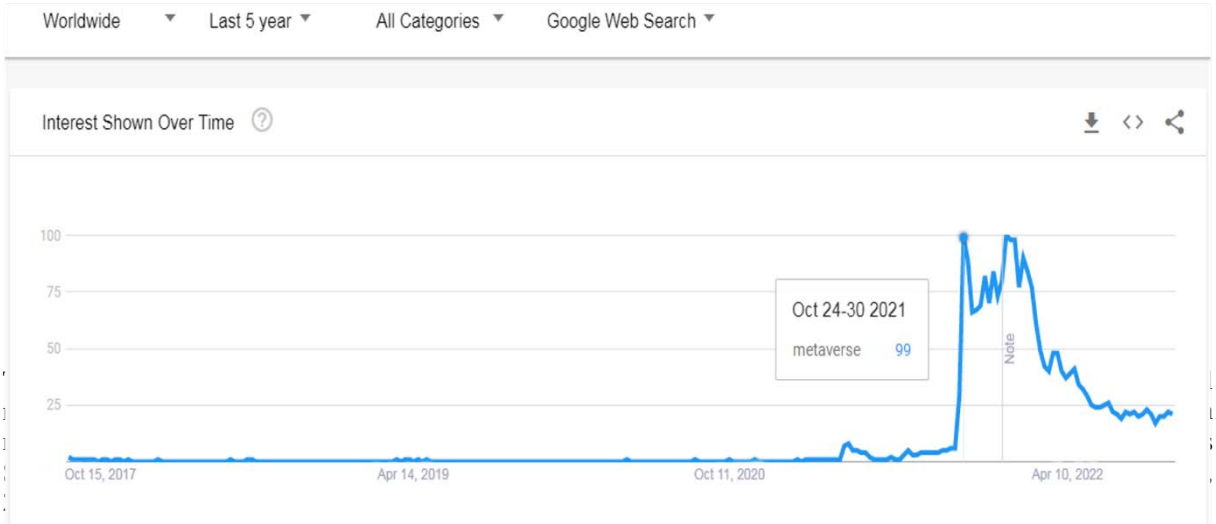
Abstract
Metaverse is a technology which allow users to “experience” a digital universe and includes several components like augmented and virtual reality. Researchers who wish to research the field may not know where to start or the key features of the field. Thus, the present study aims to discuss the general and social, conceptual, and intellectual structures of the field for future researchers on metaverse. For this purpose, the general structure, scientific maps, and socio-intellectual structure of the field were investigated. Then, recommendations are presented for future researchers by bibliometric analysis results. In the study, the abstracts and keywords in publications indexed in the Scopus database and Web of Science database were reviewed. After the data collected from 439 publications were cleaned and combined, 328 documents were analyzed using R. The performance analysis revealed that the most productive writer in the field was Ayiter E., the most influential writer was Bourlakis M., the journal with the most publications was “The Journal of the Association for Information Systems”, and the most cited study was “Avatars, People, and Virtual Worlds: Foundations for Research in Metaverses” published in that journal. The examination of the intellectual, social and conceptual framework within the field unveiled predominant associations of metaverse with keywords such as virtual, second life, augmented reality, avatar, virtual world, and virtual reality. The most frequent collaborations were between Korea, Japan and the United States on second life and e-learning.
Keywords: Metaverse, bibliometrics, performance analyze, intellectual contribution

1 Introduction

Today, financial, virtual, and physical worlds became increasingly interconnected. Imagine a virtual world where you work, shop, interact with others while you are at home: This is the metaverse! The metaverse, a technology with great potential, is a huge network where three-dimensional (3D) virtual worlds developed in real-time could work together and could be simultaneously experienced by unlimited users. The progress in technologies like augmented reality, artificial intelligence, the internet of things, virtual reality, blockchain, and gamification has sparked a growing fascination with the metaverse. (Thomason, 2022). Thus, what is metaverse?

Metaverse is a mergence of the Greek word “Meta” meaning post-after or beyond and universe. Therefore, metaverse means post-reality or transcendent universe (Mystakidis, 2022). It was used in novel "Snow Crash" of Neal Stephenson firstly. In 1992, the term was introduced to depict computer-generated 3D virtual realms where individuals engage in boundary-free interactions, detached from physical constraints. Presently, the metaverse can be defined as 3D virtual environments enabling social interaction and engagement, unrestricted by real-world limitations yet grounded in real-world analogies. (Owens et al., 2011). Merriam-Webster dictionary (2022) describes metaverse as “a persistent virtual environment that allows access to and interoperability of multiple individual virtual realities.” The popularity of the term invented in 1992 increased when Mark Zuckerberg renamed the company as “Meta” and declared that the future of the Internet was meta on October 29, 2021 (Taylor, 2022).

This could be observed in Google Trends results that reflect Google search data are (Figure 1).



According to another perspective, metaverse experiences are more than just interaction within a virtual reality (Nevelsteen, 2018). In fact, the metaverse is a mixed reality environment where real and virtual properties are combined within a continuum (Nevelsteen, 2018; Milgram & Kishino, 1994). Furthermore, this approach was not based on the contrast between real and virtual environments when describing the metaverse. This approach embodies a virtual-to-real (hybrid) spectrum, enabling the integration of virtual elements into real settings by incorporating real actions or implementing augmented reality within a virtual world, a concept termed augmented virtuality (de la Fuente Prieto, Lacasa & Martínez-Borda, 2022). This approach (Mixed Reality-MR) categorizes metaverse design based on various components presented in Figure 2.

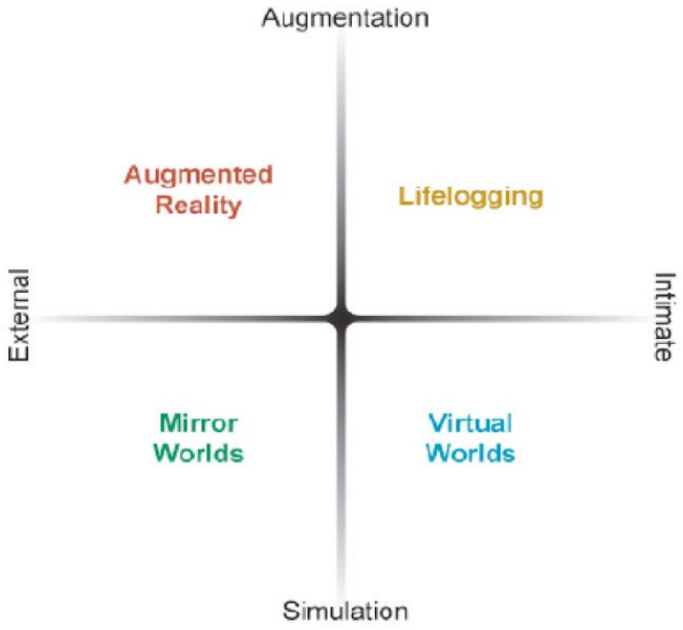


Figure 2. Metaverse Components

Smart, Cascio, and Paffendorf (2007) classified metaverse environments as follows: content (x-axis) and experiences (y-axis) (in figure 2). Experiences span from virtual simulations to augmented reality, delineated by a spectrum between personal identity (intimate) and the communal creation of worlds (external). Augmentation pertains to hardware-intensive virtual reality technologies, whereas simulation involves technologies used to simulate reality as parallel worlds. Intimate could be defined as any digital technology that allows users to take on avatars and digital profiles. External, on the other hand, is used to reflect digital technologies and tools that are not individual but rather associated with the outside world (Smart, Cascio, & Paffendorf, 2007). The terms found in the upper-right, lower-left, upper-left and lower-right sections of the graph, where these phenomena serve as the axes in Figure 2, constitute the design components of the metaverse. (de la Fuente Prieto, Lacasa, & Martínez-Borda, 2022). Augmented Reality (AR) is the most known application, and it could simply be defined as the

augmentation of the real-world with virtual elements. This common technology is employed even when taking pictures in various social media applications (Instagram, TikTok, etc.). Lifelogging involves documenting one's daily life for diverse purposes. Mirror worlds serve as virtual representations or models of the real world, enabling accessible content like Google Maps or facilitating user contributions akin to Wikipedia. Notably, the Google Arts & Culture project stands out as one of the well-recognized models. Virtual worlds remain among the most recognized environments within the metaverse landscape. (de la Fuente Prieto, Lacasa, & Martínez-Borda, 2022). Hence, the metaverse, described as a post-reality universe, constitutes a persistent and interconnected multi-user environment amalgamating digital reality and physical virtuality. In contrast to historical instances, this universe now facilitates the integration of technologies like augmented reality (AR) and virtual reality (VR), enabling multi-sensory interactions between individuals and digital objects. Consequently, metaverse technologies hold promise in surpassing the principal constraints associated with traditional web-based 2D e-learning tools. (Mystakidis, 2022). Furthermore, it could be suggested that metaverse technology would contribute to the integration of e-learning and applied courses (Kanematsu, 2014). Also, it is expected that online work settings and new commercial entertainment approaches could be developed with paradigms adequate for future metaverse technologies (Mystakidis, 2022). This would be possible due to the availability of online multiplayer video games and open game worlds, immersive, social VR platforms compatible with AR workspaces. The metaverse holds promise as a platform crafted to simulate the natural world, offering a conducive environment for researchers across diverse fields—ranging from health and sports to education and art, encompassing all facets of the humanities. (Narin, 2021). On the other hand, despite the low data availability due to the limited number of metaverse studies, certain future problems could be associated with metaverse such as cost, longer development period, information and personal data security issues, and the possibility of digital addiction.

Advances in metaverse led to higher number of research on metaverse. Researchers should analyze the current situation before research. They should also take the time to identify relevant studies, critically analyze the content and quality of available evidence, and synthesize the findings. Lack of knowledge on the research field could lead to waste of time during literature review. Thus, the availability of practical knowledge and key issues in the field would lead to an effective and efficient research. Therefore, studies on the big picture about the metaverse are required through literature review. A comprehensive literature review would help identify research points and gaps in the literature, which would be beneficial for future studies. Although there are studies on the metaverse (Duan, Li, Fan, Lin, Wu, & Cai, 2021; Wang, Su, Zhang, Xing, Liu, Luan, & Shen, 2022), the number of studies that provide an overview for researchers is limited (Linnenluecke, 2020; Narin, 2021; Tas and Bolat, 2022). The present study is different from similar studies since it aimed to determine the performance of the metaverse, as well as its conceptual, social, and intellectual structure.

Aim of this study to present a general analysis of the metaverse field for future researchers who desire to study metaverse. Thus, the study focused on two main issues. First, the performance (general information, most influential author, article, journal, and publication) was investigated to provide a holistic picture of the metaverse field. Second, the conceptual, social, and intellectual structures that allow dynamic relations in the field were investigated with scientific mapping. Therefore, the subsequent research inquiries were identified:

1. How is the performance of the metaverse field?
   - 1.1. What is the general information regarding the metaverse?
   - 1.2. Who are the most productive authors in the field?
   - 1.3. Who are the most cited authors in the field?
   - 1.4. What are the most influential publications in the field with the highest citations?
   - 1.5. Which journals hold the most influence in this field?

2. What is the conceptual, intellectual and social structure of the metaverse?
   - 2.1. What are the frequently studied keywords in the field/what are the developmental trends?
   - 2.2. What are the issues that authors in certain countries often study?
   - 2.3. What is the current state of cooperation in the metaverse domain?

2 Methodology

2.1 Research Design

In the study, bibliometric analysis was employed to review and analyze scientific publications. Bibliometric analysis is a statistical analysis method that employs database data to produce in-depth insight into the development in a particular field (Leung et al., 2017. It could be used to investigate the evolution in a field of research, based on the social, including topics and authors, intellectual, and conceptual structures of the discipline (Donthu, 2021) It allows the review of the studies, authors, institutions and scientific production in a predetermined scientific topic (Martí-Parreño et al., 2016), while objectively processing thousands, allowing authors to clearly comprehend publication trends and numerous scientific studies, even reaching tens of thousands (Ghadimi et al., 2019; Wang et al., 2020). Bibliometric studies enable the exploration of measurement of the basic properties of scientific publications in a certain field such as citations, authors, co-authors, and citations, analysis of the findings, and

determination of the trends to reveal the general structure of the field (Kasemodel et al., 2016). Bibliometric analysis methods can be applied to various fields (Lim et al., 2020), including technological predictions (Gibson et al., 2018), cloud computing research (Cai et al., 2015), and journal reviews (Wang et al., 2021). Since comprehensive bibliometric studies could provide solid and unique foundations for advance in a field (Donthu, 2021), bibliometric analysis method was adopted in the current study.
There is no standard in bibliometric analysis design. However, Donthu (2021) suggested certain guidelines for bibliometric analysis. The present study was conducted based on these bibliometric analysis guidelines (Figure 3).

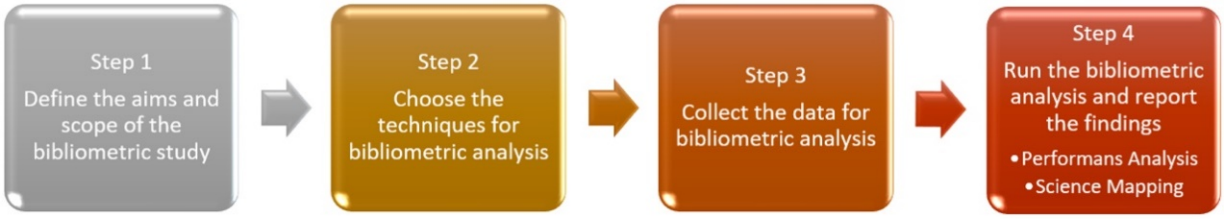


Figure. 3. Bibliometric analysis guidelines [Created benefit from Donthu et al. (2021)]

Step 1: The study's initial phase involved defining its scope and objectives. The primary aim was to offer insights into the dynamic structure of the field and to present a comprehensive analysis of the metaverse field for future researchers. The specific research questions are outlined in the introduction.
Step 2: In this step where the bibliometric research was designed, bibliometric analysis techniques were selected to meet the objectives and scope of the study that was determined in the first step (Donthu et al., 2021). Table 1 displays the bibliometric analysis techniques utilized in the study.

Table 1. Analysis techniques employed in the study [Adapted from Aria and Cuccurullo (2017); Rodríguez-Soler et al. (2020)]

Research Question	Unit of analysis	Data requirements	Bibliometric technique	Analysis technique	Structure
1 (1.1 to 1.5)	Documents	Author Publication, Journal,	Total Number of Authors, Publications, Countries, Journals,	Performance	Descriptive
2.1.	Words	Abstract Keywords	Co-word/ Co-occurrence	Science Mapping	Conceptual
2.2.	Documents	Author name Country Keywords	Bibliographic coupling	Science Mapping	Intellectual and Social
2.3.	Authors	Authors	Co-authorship analysis	Science Mapping	Social

The primary objective of the first research question was to ascertain the overall structure of the research field. Thus, performance analysis, a bibliometric analysis technique, was employed. Performance analysis entails the measurement of the scientific output in terms of dataset components (author, journal, country, institution/university) based on quality and quantity indicators. The performance analysis leads to a general picture of the field of research (Donthu et al., 2021; Aria & Cuccurullo, 2017) and explains the contribution of performance analysis components to the field. In performance analysis, citation analysis serves to identify interdisciplinary commonalities and distinctions among influential publications, authors, and journals. This method aids in understanding the connections and disparities across various fields or disciplines (Wohlin, 2008). It allows the researchers to identify popular methods, research topics and trends, as well as key variables (Gal et. al., 2004). For the analysis of the second research question data, a scientific mapping technique was utilized to unveil the conceptual and social-intellectual structure within the field. This approach specifically delves into and explores the interrelationships and correlations among different research components within the domain. (Donthu et al., 2021; Baker et al., 2021; Cobo et al., 2011). The scientific mapping technique encompasses a range of methods, including citation analysis, co-word analysis, co-citation analysis, co-authorship analysis and bibliographic coupling. These techniques prove effective in revealing both the intellectual and bibliometric structures of a research field, particularly when integrated with network analysis. The combination of these approaches enhances the comprehensive understanding of the relationships and patterns within the scholarly landscape. (Tunger & Eulerich, 2018). Co-word/co-occurrence is employed to identify thematic trends and the current situation in a particular research field, focusing on the core scientific publication content (Emich et al., 2020). The unit of

analysis is the word. In co-word analysis, words are usually determined by the keywords, abstract, title, or the full text (Baker et al., 2020; Emich et al., 2020). In bibliographic coupling, the correlations between the variables (journal, publication, author, etc.) are determined by common references. In other words, a specific citation in two articles is considered a bibliographic match. It is employed to reveal the latest developments and the current state of a field (Donthu et al., 2021). In the analysis, the developments and gaps in the field are determined based on thematic clusters across the publications. It contributes to the determination of the social and intellectual state of the field. Finally, the co-authorship analysis was employed to determine the social structure of the authors in the field. Co-authorship analysis facilitates the aggregation of co-cited authors. It also helps identify relevance and make inferences about the co-studied contexts to develop a research framework (Bu et al., 2018).
Step 3: The third step entails the preparation of the dataset for analysis. The dataset was developed in four stages: data retrieval, data output, data merge and data cleaning. The process is presented in Figure 4.

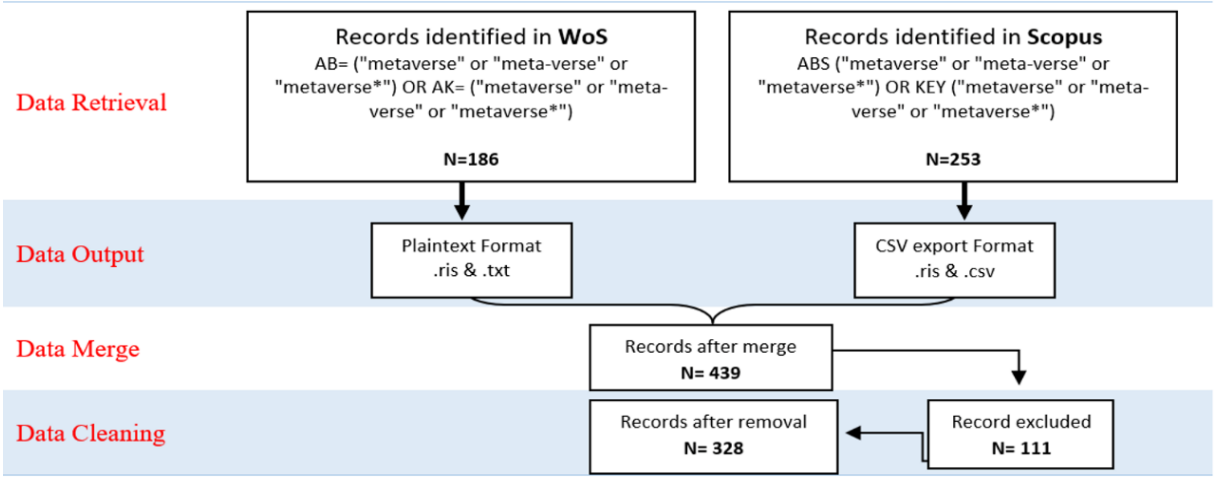


Figure 4. Preparation of the data source

The database that was employed in the data retrieval phase was determined based on exclusion and inclusion criteria, and the search strategy that included the search query. Table 2 outlines the inclusion and exclusion criteria employed in the study.

Table 2. The criteria for exclusion and inclusion

	Inclusion criteria	Exclusion criteria
Database	Scopus and WoS	Other databases
Publication period	until 17 March 2022	-
Source type	All	-
Document type	All	-
Subject area	All	-
Language	All	-

WoS and Scopus databases were searched since the data output formats of these databases were compatible with the Bibliometrix R software, which was employed in bibliometric analysis. The research was conducted in the WoS database, where Select All Fields was selected in the Advanced Search section, and the Query Preview entry was as follows: *AB=("metaverse" or "meta-verse" or "metaverse*") OR AK=("metaverse" or "meta-verse" or " metaverse*")*. The query aimed to search for keywords associated with metaverse in abstract and keywords sections. The Scopus database was queried with the following code: *ABS("metaverse" or "meta-verse" or "metaverse*") OR KEY("metaverse" or "meta-verse" or "metaverse*")*. WoS search revealed 184 records on 17.03.2022 and Scopus search revealed 252 records. In the data output stage, the data should be converted into an adequate format for bibliometric tools (R in the article). The WoS data were saved in 'plaintext' format with .ris and .txt extensions (export→ citiation information, bibliographical inf, abstract & keywords, Funding details, other inf.). The Scopus data were saved in 'CSV export' format with .ris and .csv extensions (export→citiation information, bibliographical inf, abstract & keywords, Funding details, other inf.). The data merge stage revealed 439 records. Once the adequate data are identified, duplicates should be removed from the analysis. Indeed, while bibliometric data are often confidential, challenges can arise in the recording of data. Issues such as variations in the spelling of authors' names, multiple versions of the same publication, complications with common names, diverse spellings of journal titles, and discrepancies in book editions are common pitfalls in the bibliometric data

collection process. These challenges underscore the importance of meticulous data management and standardization procedures to ensure accuracy and reliability in bibliometric analyses. Thus, the data should be cleaned. As mentioned in the data merge stage, 111 data were removed from the dataset and the analysis was conducted on 328 records.

Step 4: In the concluding phase, a bibliometric analysis was carried out, and the results were presented. The Bibliometrix R software played a pivotal role in importing bibliographic data, conducting bibliometric analysis, and constructing data matrices for co-citation, consolidation, co-word analysis, and collaboration analysis. R stands out as one of the most potent, adaptable, and open-source statistical software, making it a valuable tool for comprehensive and rigorous bibliometric examinations. (Aria & Cuccurullo, 2017). It also provides an extensible and flexible free environment for research and analysis (Linnenluecke et al., 2020). The analysis findings are reported in network visualization maps and tables.

3 Findings

3.1 Performance of the Metaverse field

3.1.1 Primary information about data sources

To evaluate the performance of the metaverse field, an initial descriptive analysis was performed, and the results are outlined in Table 3.

Table 3. Fundamental details regarding the sources of data

Description	Result	Description	Result
GENERAL INFORMATION OF DATA		Editorial material; book chapter	1
Timespan	1995:2022	Proceedings paper	57
Sources (Books, Journals etc.)	250	Review	5
Documents	328	DOCUMENT CONTENTS	
Average years from publication	7,62	Keywords Plus (ID)	906
Average citations per documents	6,829	Author's Keywords (DE)	927
Average citations per year per doc	0,6909	AUTHORS	
References	8882	Authors	630
DOCUMENT TYPES		Author Frequency	859
Article	137	Authors of single-authored documents	74
Article; book chapter	16	Authors of multi-authored documents	556
Article; early access	6	AUTHOR COLLABORATION	
Book	2	Single-authored documents	110
Book chapter	16	Documents per Author	0,521
Conference paper	68	Authors per Document	1,92
Conference review	11	Co-Authors per Documents	2,62
Editorial	2	Collaboration Index	2,55
Editorial material	7		

Note: The Authors per Document Index (APDI) indicates the ratio of total authors to total documents, offering insights into the average number of authors per document in a specific context (e.g., 630/328 = 1.92). The Co-authors per Document Index, reflecting collaboration intensity, calculates the average co-authors per document (e.g., 859/328 = 2.618). APDI consistently yields lower values than the Co-authors per Document Index because it counts each author only once, while the latter considers all co-authors, providing a more comprehensive measure of collaboration. The Collaboration Index (e.g., 556/(328-110) = 2.55) assesses the ratio of authors in multi-authored documents to the total count, indicating collaborative patterns. (Chakraborty et al., 2021)

Table 3 includes descriptive dataset statistics such as main information, document types, document content and author. It was observed that the word metaverse has been used in the literature since 1995. The total number of papers in the field was 250, and the number of documents was 328 between 1995 and 2022. This total was consistent with the data count presented in Figure 4. The papers were cited every 8 (7.63) years on average. Each paper was cited 7 (6.82) times on average. All papers collectively received a total of 8882 citations. This provides an overview of the dataset based on the time period, total number of papers, total number of documents, mean year

since publication, average annual citation per document, mean citation per document and total number of citations. All document types were included in the study to determine the publications. There were 12 types of publications and 328 papers on metaverse. Most common documents were articles (137), proceedings (68), book chapters (16) and article chapters (16). The analysis of document content revealed 906 automatically generated keywords in bibliographical titles and 927 keywords determined by the authors. There were 630 authors in the field, while the total number of contributing authors and the number of papers they authored was 859. Seventy-four authors published alone, while 556 collaborated with others. When two or more authors published a document, the authorship was considered collaborative. There were 110 single-authored documents, averaging 0.521 documents per author, with an approximate ratio of 2 authors per document and 3 authors per document. The Collaboration Index (CI), indicating collaborative trends, yielded a coefficient of 2.55 in the metaverse field.

3.1.2 The most productive authors

One of the main factors that determine the performance of the field is the author data. Therefore, the productivity of each author in the dataset (total 630) was assessed based on the number of publications, and the top five most productive authors are outlined in Table 4.

Table 4. Five most productive authors

Authors	Affiliation	Country	NP	AF
Ayiter, Elif	Sabanci University	Turkey	19	17,83
Schlemmer, Eliane	Universidade do Vale do Rio dos Sinos	Brazil	16	7,83
Backes, Luciana	Centro Universitario La Salle	Brazil	14	7,5
Fukumura, Yoshimi	Nagoka Univ Technol	Japan	6	0,95
Kanematsu, Hideyuki	National Institute of Technology	Japan	6	0,93
Note: NP= Number of publications; AF= Articles Fractionalized				

These authors were ranked based on number of publications. Thus, the most productive authors were Elif Ayıter (19) from Sabancı University in Turkey, Eliane Schlemmer (16) from Centro Universitario La Salle, Brazil, Luciana Backes (14) from Centro Universitario La Salle, Brazil, and Yoshimi Fukumura (6) from Nagoka Univ Technol and Hideyuki Kanematsu (6) from the Japan National Institute of Technology, Japan. Also, Elif Ayıter (17.83) made the highest contribution based on AF figure.

3.1.3 The most cited authors

In the metaverse field, the number of times an author was cited by other authors was analyzed based on g-index, h-index, total number of citations, m-index and number of publications. The five most influential authors are presented in Table 5 based on total citations.

Table 5. Five most cited authors

Author	g_index	h_index	m_index	TC	NP	PY_start
Papagiannidis, Savvas	3	3	0,2	134	3	2008
Bourlakis, Michael	3	3	0,2	134	3	2008
Khazanchi, Deepak	4	3	0,214	125	4	2009
Owens, Dawn	4	4	0,214	125	4	2009
Zigurs, Ilze	3	3	0,214	123	3	2009
Note: TC: Total citations; PY_start: Publication year start; NP: Number of publications						

Although the number of publications by Papagiannidis and Bourlakis, which were ranked at the top in Table 5, was only 3, these papers were cited the most (134). Furthermore, their g-index (3), h-index (3), m-index (0.2) and the year of publication (2008) figures were the same. Although the number of publications by Khazanchi and Owens, who ranked third and fourth, was 4, their studies were cited 125 times [g-index (4), h-index (3), m-index (0.214)]. Also, the year of publication (2009) was the same. Finally, Zigurs started publishing on metaverse in 2009 and published 3 papers [g-index (3), h-index (3) and m-index (0.214)].

3.1.4 The most influential publications based on citations

One of the main factors that determine the performance of the field is the reference data. Thus, each article in the dataset (total 250) was analyzed based on total number of citations and the first five results are presented in Table 6.

Table 6. Five most cited documents

Title	Source	Author	P.Year	DOI	TC	TCY
"Avatars, People, & Virtual Worlds: Foundations for Research in Metaverses"	J1	Davis, A. et al.	2009	10.17705/1jais.00183	107	7,6429
"Making real money in virtual worlds: MMORPGs & emerging business opportunities, challenges and ethical implications in metaverses"	J2	Papagiannidis, S., Bourlakis, M., & Li, F.	2008	10.1016/j.techfore.2007.04.007	63	4,2
"Second Life & the New Generation of Virtual Worlds"	J3	Kumar, S. et al.	2008	10.1109/MC.2008.398	60	4
"Modelling the determinants of a simulated experience in a virtual retail store and users' product purchasing intentions"	J4	Papagiannidis, S. et al.	2013	10.1080/0267257X.2013.821150	41	4,1
"3D Virtual worlds and the metaverse"	J5	Dionisio, J. D. N., III, W. G. B., & Gilbert, R.	2013	10.1145/2480741.2480751	37	3,7
Note: J1: "Journal of the Association for Information Systems"; J2, "Technological Forecasting and Social Change", J3: "Computer", J4: "Journal of Marketing Management", J5: "ACM Computing Surveys", PY: Publication Years, TC: Total citation, TCY: Total citation year						

As seen in Table 6, Davis et al.'s (2009) "Avatars, People, & Virtual Worlds: Foundations for Research in Metaverses" was cited the most in total (107) and annually (about 8 per year). This paper was followed by "Making real money in virtual worlds: MMORPGs & emerging business opportunities, challenges and ethical implications in metaverses" by Papagiannidis et al. (2008) with 63 citations. This article receives about 4 citations per year. "Second Life and the New Generation of Virtual Worlds" by Kumar et al. (2008) ranked third with 60 citations and 4 citations per year. "Modeling the determinants of a simulated experience in a virtual retail store & users' product purchasing intentions" by Papagiannidis et al. (2013) was the fourth with 41 citations and about 4 citations per year, followed by "3D Virtual worlds and the metaverse" by Dionisio et al. (2013) with 37 citations and about 4 citations per year. It was observed that the most cited articles were published after 2008, and the most cited articles were relatively few in 2013. Furthermore, the top five most cited articles were distributed across various journals.

3.1.5 The most influential journals

The journal performance was analyzed based on g-index, m-index, h-index, total number of publications and total number of citations variables. The first five journals based on total number of citations are presented in Table 7. This analysis measured whether the articles published in journals contributed to the field.

Table 7. Five most cited journals

Element	h_index	g_index	m_index	TC	NP	PY
"The Journal of the Association for Information Systems"	2	2	0,142	136	2	2007
"Technological Forecasting and Social Change"	1	2	0,067	64	2	2008
"Computer"	1	1	0,067	60	1	2008
"Electronic Commerce Research"	2	2	0,143	54	2	2009
"International Journal of Health Geographics"	2	2	0,125	49	2	2007
Note: TC: Total citations; PY: Publication year; NP: Number of publications;						

As seen in Table 7, the "Journal of The Association for Information Systems" was the most influential journal in metaverse research. Two articles published in the journal were cided 136 times. Technological Forecasting and

Social Change journal ranked second with 60 citations for two articles. An article published in Computer magazine ranked the journal third with 54 citations. Two articles published in the Electronic Commerce Research journal were ranked fourth with 49 citations. Finally, two articles published in the International Journal of Health Geographics were cited 49 times. However, although the publication year, h_index and g_index values were similar, there was a difference between the m_indexes of the journals.

3.2 The conceptual, intellectual structure and social structure of the metaverse field

3.2.1 Frequently studied keywords / development trends in the field

To determine the trends in metaverse research and the correlations between the keywords, co-word analysis was conducted and the term metaverse was excluded from the analysis. The common keywords in 1107 articles published between 2004 and 2021, in other words, the topical structure of the metaverse research is presented in Figure 5.

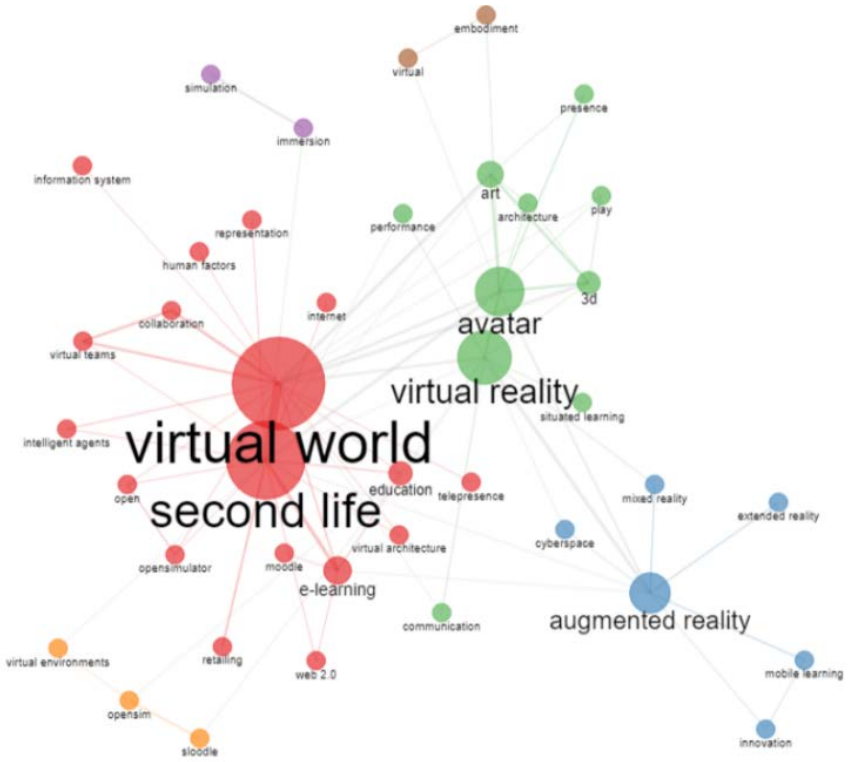


Figure 5. Common keyword frequencies in papers published between 2004 and 2021

Note: The size of the circle indicates the frequency of the keyword, and the weight of the link indicates the strength of the correlation.

The list of frequently used keywords is presented in Figure 5. Forty-one keywords were mentioned in the abstracts or keywords and formed 6 clusters presented in 6 colors (second life, augmented reality, avatar, immersion, virtual environments and embodiment, respectively). The cluster reflects different topics/fields of study. A thicker line between the clusters indicates a stronger correlation between the keywords. However, keywords with no or very weak lines indicate a zero or weak correlation. Thus, the first five keywords were analyzed based on betweenness. These were the second life, avatar, virtual world, augmented reality and virtual reality. Analysis of all keywords is presented in the appendix.

3.2.2 Frequetly studied topics by certain author groups in certain countries

In the study, three variables (word-author-country) were determined to investigate the intellectual and social structure. Three-fields plot was used to analyze the correlations between these variables and presented in a Sankey diagram (Figure 6). The diagram allows a better comprehension of the social structure not only of the authors but also of their countries.

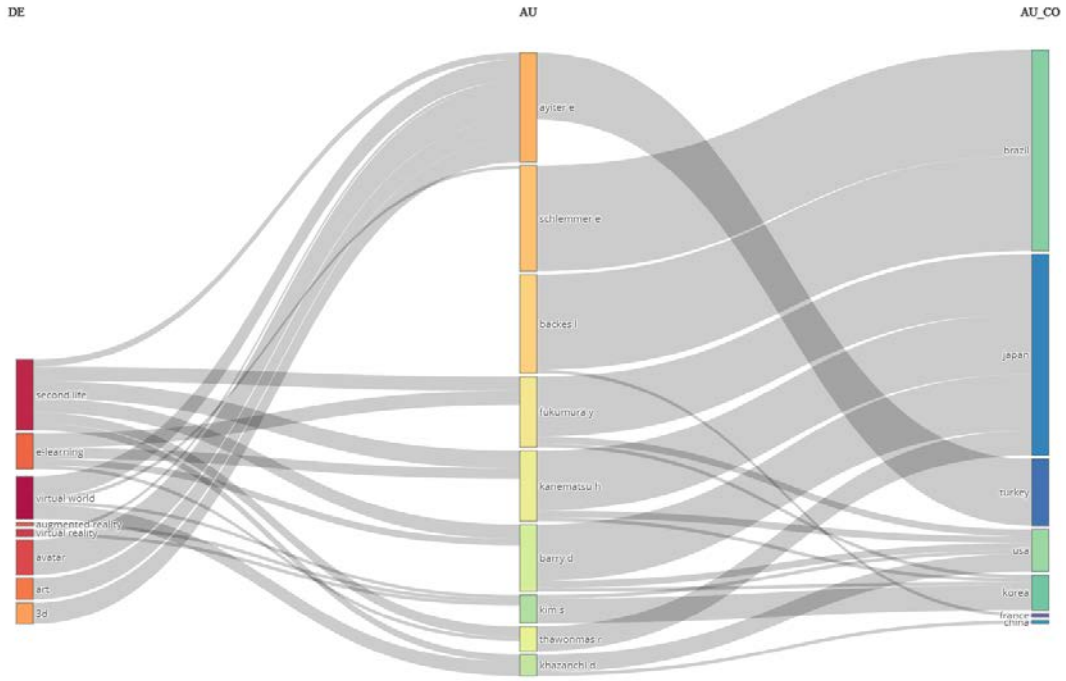


Figure 6. Country, author and keyword Sankey diagram

Sankey diagrams are often used to show weighted networks and connections between two or more nodes (or domains). Rectangles represent these nodes, and the connections are indciated by arrows with a width that reflects the significance of the correlation (Holtz, 2018). The correlation between the countries (left), the authors (middle), and the keywords (left) are presented in Figure 6. In a Sankey diagram, the widths of both the arrows and boxes are directly proportional to the quantity or magnitude of publications they represent. This proportional scaling visually emphasizes the volume or flow of data, illustrating the relative size or significance of different elements within the diagram (Soundararajan et al., 2014). The diagram reflects the links between country-author-word and different countries. The border width of the country box exhibits that the country performance in the field of metaverse. Active countries were Brazil, Japan, Turkey, America, Korea, France and China, respectively. Based on the diagram, the analysis of the first three countries revealed that Brazil conducted research on the virtual world metaverses field. Brazil collaborated with France. Similarly, Japan collaborated with the US and Korea in research on Second Life and e-learning. It was observed that Turkey, which ranked third, conducted studies in the field other than e-learning and did not collaborate with any country. Based on the study topics, Fukumura, Kanematsu and Barry from Japan conducted studies mostly on Second Life and e-learning, Ayiter from Turkey and Khazanchi from the US conducted studies mostly on virtual worlds, Kim from Korea conducted studies mostly on augmented reality and virtual reality, and Ayiter from Turkey conducted studies mostly nn avatars, art and 3D.

3.2.3 Collaboration in metaverse research

A co-author analysis was conducted to determine the social structure and cooperation in metaverse research. Co-author analysis investigates the interactions between academicians in a research field (Donthu, 2021). The author collaboration network is presented in Figure 7.

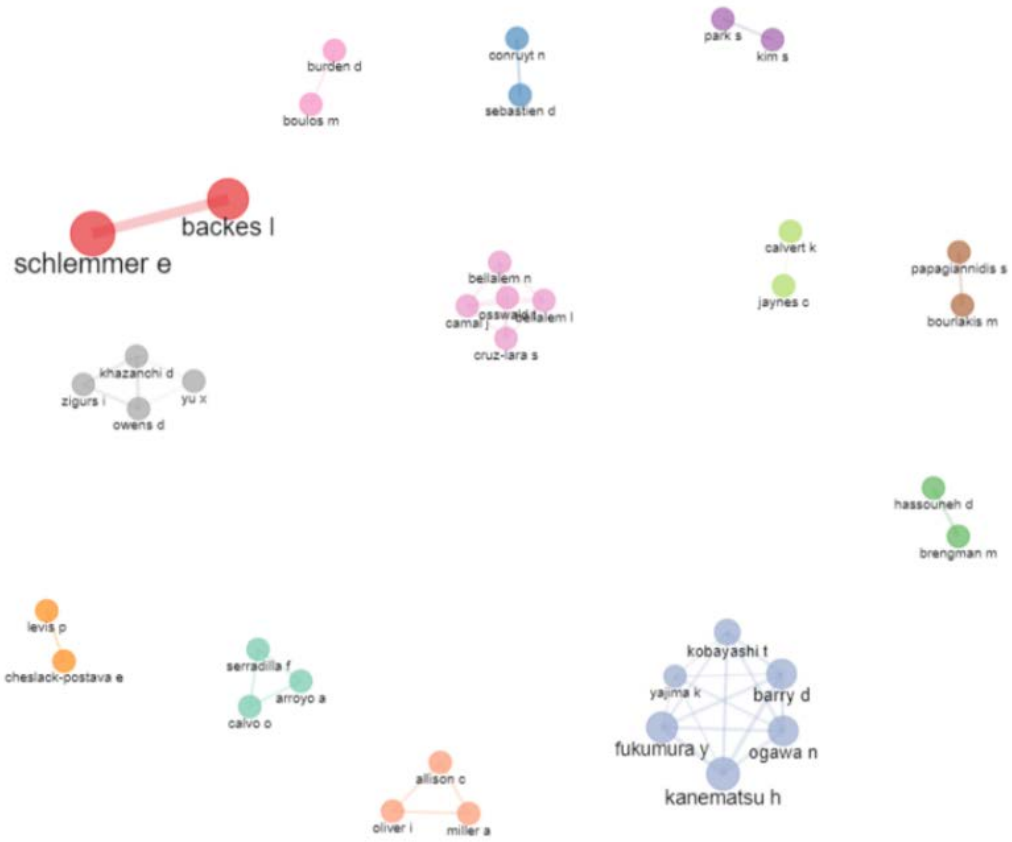


Figure 7. Author Network of Collaboration

In Figure 7, the node size reflects the number of publications by each author, and the thickness of the connection reflects the number of co-publications. It was observed that collaboration was sparse in metaverse research. The analysis of the colors revealed that the authors could be categorized in 13 research communities. The largest central node (the network core) included six researchers; Kanematsu H., Ogawa N., Barry D., Fukumura Y., Kobayashi T., and Yajima K. It was also observed that the number of co-publications by Schlemmer E and Backes L. was high. With the exception of a few isolated co-authorship groups, the broader network appears highly fragmented, suggesting that collaboration within the field is currently limited in scale. Prolific authors tend to be situated within dense clusters, characterized by sparse connections to individuals outside of their immediate scientific circles. This pattern underscores a prevailing lack of extensive collaboration within the larger network.

4 DISCUSSION

4.1 The performance of metaverse research

The performance of the metaverse field was determined with descriptive analysis. Initially, this overview could be used as an introduction to the performance of the research topic (Ahmi, 2022). Then, the most productive author, the most cited author, the most influential publications and the most influential journals are investigated. The data collected with this method could provide an overall picture of the dataset.

In descriptive analysis, the publication period, the total number of documents, the total number of publications, average annual publications, the average citations per paper, the average annual citations per paper and the total number of references, etc. are analyzed. One of the important findings in this analysis was that the first metaverse paper was published in 1995. Since then, metaverse studies have been published for 27 years. However, it was reported in the literature that the concept of metaverse was first employed by Neil Stephenson in his science fiction novel Snow Crash in 1992 (Stephenson, 1992). Park and Kim (2022) also mentioned this in their study “A Metaverse: Taxonomy, Components, Applications, and Open Challenges”. Abbate et al. (2022) reported that the concept of metaverse emerged in 1992; however, they mentioned 2003 as the first year of publication. Tas and Bolat (2022) reported that initial studies were published in 1994, while Narin (2021) mentioned 2005. These differences were due to the scope and coverage criteria determined by the researchers during the development of the dataset. Abbate (2022) reviewed the articles that included the term "metaverse" in title, abstract or keywords in the Scopus database. Tas and Bolat (2022) conducted a different query (“Metaverse” OR “Second Life” OR

"Virtual Reality" OR "Virtual Worlds" OR "augmented reality"), filtering educational scientific research, articles and English language papers in WoS database. Similarly, Narin (2021) investigated the publications that included the "metaverse" keyword in all journals in the WoS database and those that were indexed in the SCI-Expanded, SSCI, A&HCI, ESCI indices. It was also determined in the current study that only 328 papers were published in 27 years, an average of 12 papers per year. This was due to the fact that the researchers only focused on the field in recent years. Taylor (2022) reported that the interest in metaverse research increased after Mark Zuckerberg renamed his company Facebook as "Meta" in 2021. Another significant finding in the current study was that the most prolific author in metaverse research was Elif Ayiter of Sabancı University (Turkey), Faculty of Arts and Social Sciences. Damar (2021), who conducted a bibliometric analysis of the metaverse research, reported the same finding. Ayiter is a designer and researcher. She is also the chief editor of the "Metaverse Creativity with Intellect Journal". Metaverse design and application include several components since various environments such as AR, VR, AI, IoT could be employed. It was determined that Ayiter focused on the avatar visual design component. This also reflected the multidisciplinary aspect of the metaverse. Although Ayiter was the most prolific writer, the most cited authors were Savvas Papagiannidis and Michael Bourlakis. The difference between the most productive writer and the most influential writer was based on different measurements. While the most prolific author was determined based on the number of publications, the most cited author was determined by the citations that an author (or a paper) in the most influential author dataset received (Aria & Cuccurullo, 2017). Although the authors had no collaborations with others (Papagiannidis et al., 2008), the study was determined as the second most influential (most cited) article in the dataset. Also, other authors on the list (Deepak Khazanchi, Dawn Owens and Ilze Zigurs, respectively) collaborated with Papagiannidis. Davis et al. (2009) was determined as the most influential article in the field. Based on research topics (e-business, e-marketing, e-commerce, information systems, digital innovation & transformation, food supply chain, retail supply chain, B2B, risk management, virtual project management, virtual worlds, mental models, applied ML, etc.), the multidisciplinary feature of metaverse was significant. Papagiannidis et al. (2008) noted that metaverses allow both interdisciplinary and multidisciplinary research. The most influential article was "Avatars, People, and Virtual Worlds: Foundations for Research in Metaverses" by Davis et al. (2009). Similarly, Abbate et al. (2022) reported that this was the most cited article. It was one of the articles reviewed by Narin (2021). Davis et al. (2009) conducted an in-depth analysis of virtual worlds such as World of Warcraft and Second Life, which were considered novel technological platforms back then. They developed a conceptual model for metaverse research. The model was based on five key constructs: people/avatars, metaverse, capabilities of the metaverse technology, behaviors, and outcomes. Since Second Life and Metaverse were trending in 2009, this study, which investigated the conceptual structure, was one of the building blocks of virtual world research. Papagiannidis et al. (2008), in "*Making real money in virtual worlds: MMORPGs & emerging business opportunities, challenges and ethical implications in metaverses*", investigated the business opportunities and challenges in a virtual world such as Second Life based on ethical and policy concerns. The review of the five articles revealed that the similarities included virtual worlds and Second Life. This was due to the fact that the Second Life virtual game was launched in the early 2000s and became quite popular. Davis et al. (2009) was published in "The Journal of the Association for Information Systems (JAIS)", one of the most influential journals. It is comprehensive in terms of topics, unit and level of analysis, method, theory and scientific research approach and reflects all aspects of Information Systems globally. This journal has an h-index of 85. The best quartile for this journal is Q1. Based on the year that the journal started publication (2007), virtual worlds have been one of the current issues and adequate for the journal.

4.2 The conceptual intellectual structure and social structure of metaverse research

The conceptual structure of the metaverse research demonstrated that the keywords Second Life, avatar, virtual world, virtual reality and augmented reality were employed, and these had a thematic relationship. Co-word analysis operates on the assumption that words frequently appearing together share a thematic relationship (Donthu, 2021). Due to the wide-range and ever-growing nature of the metaverse research, various definitions and similar concepts coexist. Thus, these words are in a closer and stronger relationship with the metaverse research. This finding was consistent with the descriptive analysis conducted by Narin (2021). Park and Kim's (2022) definition of the metaverse (a 3D virtual world that avatars engage in economic, political, social and cultural activities) includes the same words. It was also observed that these words were frequently associated with metaverse in various studies (Kye et al., 2021; Park and Kim 2022). There are two reasons for this. The first is the christening of Second Life as a metaverse (Papagiannidis et al., 2008). Another reason stems from the conceptual structure, approach and basic components required to create a metaverse. Park and Kim (2022) discussed the concepts and basic techniques required to create a metaverse based on three components (hardware, software and content) and three approaches (user interaction, implementation, and application). They also discussed the concepts of virtual world, avatar, augmented reality and virtual reality in their study. In brief, to create a metaverse, a virtual world (i.e., second life), technologies required by this world (i.e., augmented reality and virtual reality) and avatars are required. To analyze the intellectual and social structure of metaverse research, the correlations and flow between the keywords, authors and countries were investigated. The most significant correlation between

the countries was observed between Japan and the US in Second Life and e-learning research. This could be since Linden Research, Inc., the developer of Second Life, is an American company. Furthermore, the fact that Japan is advanced in technologies and had the highest number of authors could explain the collaboration between American and Japanese authors. It was also significant that Ayiter employed a higher number of keywords when compared to other authors. This indicated a significant coverage. It is important to understand the interaction between the scientists. The co-author analysis findings revealed the intellectual collaboration across scientists. The analysis revealed cooperation among Korean, Japanese and American authors, as seen in the Sankey diagram, within a network that included six researchers. The authors published a joint study titled "*Multilingual Discussion in Metaverse among Students from the USA, Korea and Japan*". Co-authorship represents a formal intellectual collaboration among scholars (Cisneros et al., 2018) and It is crucial to comprehend the dynamics of scholars' interactions (Donthu, 2021). The work of collaborating researchers creates a network called "invisible collages," which could facilitate research initiatives (Crane, 1969). The authors who published the most collaborative studies were Schlemmer and Backes. The study findings revealed that authors from the same country or who study the same topics created research teams and each team worked independently.

4.3 Recommendations

Certain recommendations are presented for upcoming studies relying on bibliometric analysis. Based on the performance of the field, several types of papers have been published (articles, books, proceedings, etc.) in the field of metaverse. The most influential publications were articles and proceedings. Thus, the publication in each paper type would contribute to the field.

4.3.1 Recommendations on the performance of metaverse research

Certain recommendations are presented for upcoming studies relying on bibliometric analysis. Based on the performance of the field, several types of papers have been published (articles, books, proceedings, etc.) in the field of metaverse and the most influential publications were articles. Publications in various types would contribute to the field from different perspectives. Since it was determined that there is a need for future in-depth studies, the authors may prioritize articles. The most influential and productive authors and their work should be taken into consideration when determining a study topic on metaverse. Thus, the most prominent authors (Ayiter, Schlemmer, Backes, Fukumura, Kanematsu), the authors with the most influential publications (Papagiannidis, Bourlakis, Khazanchi, Owens, and Zigurs) and their work should be reviewed. The diversity across the most influential and most productive authors would provide various perspectives. Then, future authors could learn the building by reviewing the most influential work. Thus, the authors could develop a roadmap. The most cited articles could help discover dominant fields in related sciences. Also, highly cited articles could be employed to improve the acceptability and visibility of future papers. Submitting the articles to the journal that published a higher number of studies would also improve the chance of publication and visibility of their works. Since the journal was in Q1, they could first submit their work to "The Journal of the Association for Information Systems". As in any publication process, the aim and scope of the journals should be considered.

4.3.2 Recommendations on the conceptual, social, and intellectual structure of metaverse

Better comprehension of metaverse research requires the determination of a starting point. Thus, the keywords determined in the present study, especially second life, augmented reality, virtual world, virtual reality should be investigated. The similarities and differences between the environments would help understand the metaverse better and build future studies on solid foundations. The employment of keywords is important for visibility and therefore readability of the paper. Therefore, they may prefer these keywords (based on the study topic). Authors could save time by reviewing the literature based on their selected topic. For example, researchers who want to study Second life should review the studies by Fukumura, Kanematsu and Barry, those who desire to study avatars, art and 3D should review Ayiter's publications. Collaboration between researchers in different countries would provide different perspectives and expand professional networks.

4.3.3 Recommendations on research scope

The findings of the present article would provide information on metaverse research trends based on specified criteria. Nevertheless, future studies should address certain limitations. For instance, the present investigation primarily concentrated on visualizations and link maps related to words, publications, authors, journals, and collaborations. Thus, for a comprehensive approach to the field of metaverse, the current bibliometric study findings should be complemented with a comprehensive content analysis based on the review of the publications in the dataset. Only WoS and Scopus database were employed in the study. Although these databases are reliable data repositories for bibliometric work, certain significant studies indexed in other databases could have been missed. The measurement used to analyze journal performances was the number of related publications. Thus, other journal performance indicators such as Altmetrics could be considered in future studies.

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