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Review

Mapping Metaverse Research: Identifying Future Research Areas Based on Bibliometric and Topic Modeling Techniques

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Abstract: The metaverse represents an immersive digital environment that has garnered significant attention as a result of its potential to revolutionize various industry sectors and its profound societal impact. While academic interest in the metaverse has surged, a dearth of comprehensive review articles employing bibliometric techniques remains. This study seeks to address this gap by analyzing 595 metaverse-related journal articles using bibliometric and topic modeling techniques, marking the first of its kind to investigate the bibliometric profile of metaverse research. The findings reveal exponential growth in metaverse research since 2020, identifying major trends, prolific authors, and the most active journals in the field. A keyword co-occurrence analysis further uncovers four significant clusters of metaverse-related interests, highlighting its unique facets and underscoring its far-reaching implications across various sectors, including education, healthcare, retail, and tourism. This study emphasizes the need for more research and collaboration in advancing the metaverse field and presents 27 research questions for future investigation. This comprehensive analysis serves as a foundation for understanding the current state of metaverse research and its potential trajectory.

Keywords: metaverse; education; healthcare; tourism; immersive digital environment; research agenda; research questions

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1. Introduction

The metaverse can be defined as a "perpetual and persistent multiuser environment, merging physical reality with digital virtuality" [1] (p. 486). It has its roots in the pioneering works of Morton Heilig, who created a virtual reality machine in the 1960s, and Ivan Sutherland, who described the merge of the physical and digital worlds in his seminal 1965 article entitled "The Ultimate Display" [2]. The metaverse is predicted to be the next step in digital advancement, offering the potential to revolutionize the level of digitalization and expand the range of available services beyond traditional online systems [3–5]. Over the past few years, the use of digitalizing services has become a popular trend for improving efficiency across various fields, including entertainment, business, and education [6–9]. The systems and services of the metaverse have been continually enhanced by making use of digital technologies, cloud platforms, and remote data centers to leverage online storage and processing capabilities [10,11]. As service access quality and performance continue to increase their maximum potential, there is a greater emphasis on enhancing the consumer experience. As a result, there is an increasing demand for more interactive and immersive service experiences [12]. Service providers are thus striving to enhance their current standards and practices to meet this demand. This satisfies the demand for more immersive digital experiences with emerging technologies, such as virtual reality (VR) [13], augmented reality (AR) [14–16], mixed reality (MR) [17], and extended reality (XR) [18]. In a global setting, the metaverse brings together various promising technologies, creating a simulated environment that users can immerse themselves in as a virtual world [19–21].

Users' digital avatars, which follow the duality principle [22], allow them to engage with this virtual environment. Conceptually, avatars are digital representations of their owners, and as such, they are accorded the same rights in the virtual ecosystem that their owners possess in the real world [23,24]. This ensures the validity of all transactions carried out in the virtual ecosystem and eliminates the possibility of any activities taken within it being repudiated. To access the metaverse, a VR headset or AR glasses—with even the most basic features—are required [25]. Immersive haptic garments, such as the HoloSuit or Teslasuit, have the capability to elevate immersion to its fullest extent. These bodysuits can track motion, provide haptic feedback, and capture biometrics, taking the immersive experience to the next level.

The metaverse was initially designed to expand the possibilities of social media, but its potential in other sectors, such as commerce, education, government, tourism, military, and healthcare is enormous [6,26–28]. Remote online access and control systems are often criticized for their lack of an immersive experience, particularly in the case of remote automation systems based on programmable logic controllers (PLCs) or supervisory control and data acquisition (SCADA). Other areas that require innovation include fitting apparel, commercial real estate or architecture perception, 3D visualization in engineering or healthcare education, and the remote control of drones. Although VR and AR technologies have delivered numerous solutions, what has been lacking is a unified platform or environment in which these tools can be combined. The metaverse provides this digital setting, ushering in numerous opportunities.

According to Ferreira et al. [29], it is critical for researchers to periodically reflect on the knowledge they have produced and gathered to identify research traditions, trends, and emerging topics in their field. This reflection can inspire contributions and help researchers understand the intellectual structure and knowledge body of their field, including the methods and theories applied and the subjects covered. One technique for understanding the knowledge landscape of a particular scientific field is scientography, which involves the graphic detection of hidden patterns in the field [30]. Scientography is similar to cartography and landscape mapping in terms of its use of information visualization to create clear and simple representations of complex data. However, the primary goal of scientography is to track the knowledge structure of a particular academic domain and identify areas of research that are particularly active and promising [31]. To achieve this goal, scientography employs a variety of tools and techniques, including high-performance computers, advanced visualization techniques, and the use of digital databases. By combining these tools with the insights of domain experts, scientography can help researchers to better understand the intellectual structure of their field and to identify research hotspots or frontiers that may be ripe for exploration. Ultimately, the aim of scientography is to support the growth and development of scientific knowledge by facilitating the discovery of new and important research questions.

The past few years have witnessed significant growth in the literature pertaining to the metaverse, with several reviews exploring various dimensions of this field. For example, Kye et al. [32] categorized the metaverse into four types and explored its potential and limitations as an educational tool, providing examples of AR in medical education and suggesting future tasks for its educational use. Similarly, Tlili et al. [33] systematically reviewed the literature on the metaverse in education, analyzing trends and limitations by way of content and bibliometric analysis. The authors identified a research gap in lifelogging applications and a lack of focus on certain types of learning and students with disabilities. Petrigna and Musumeci [34] synthesized the literature connecting the metaverse with prevention and treatment, education and training, and research. Their review findings indicate that a limited number of studies have discussed the potential use of the metaverse in these areas; hence, more research is required to devise effective health-promotion programs in the metaverse. Other reviews on the metaverse in the health sector have also been conducted recently [35–39]. From the perspective of the industrial metaverse, Mourtzis et al. [40] discussed the implications of blockchain technology for safe and intelligent manufacturing and highlighted its potential for data validity protection, communication organization, and efficiency improvement while overcoming cybersecurity challenges. Pooyandeh et al. [41] analyzed cybersecurity in the metaverse in light of various technologies (e.g., AI, blockchain) and highlighted the role of user identification and the need for a cyber-situation management system based on AI algorithms. Baghalzadeh Shishehgarkhaneh et al. [42] conducted a bibliometric and systematic literature review to analyze the use of building information modeling, the Internet of Things (IoT), and digital twins in the construction industry. The identified themes from the study include smart contracts, ontology, VR and AR in building information modeling, and digital twins, while the opportunities for future research relate to the relationships among BIM (building information modeling, i.e., the digital representation of physical places), the metaverse, AI, metaheuristic algorithms for optimization in BIM, and the circular economy. In connection to social and ethical considerations, Bojic [43] investigated the role of the metaverse in shaping future relations of power and media addiction levels in society. Kshetri [44] analyzed the political, national, global, geopolitical, social, ethical, and environmental concerns related to the metaverse. The author argued that the appearance of geopolitical aspects and potential cyberwarfare tactics in the metaverse, which involve stealing biometric data and financial information, could escalate cyber conflicts and lead to tensions between nations. In the context of marketing, Shen et al. [45] explored how application design paradigms and consumer behavior are related in virtual commerce through a systematic literature review that identified significant factors in promoting purchase and design elements in the metaverse. Anonymous [46] provided a concise overview of global management trends, drawing practical insights from current research and case studies, with a particular focus on the use of the metaverse to enhance customer experiences in the hospitality industry. Finally, articles by Lee and Kwon [47] and Lee and Kwon [48] explored potential changes in the cosmetic industry, with the former analyzing changes in consumer perception and the latter focusing on the introduction of luxury cosmetic brands using non-fungible tokens (NFTs) in the metaverse world.

Existing systematic review studies on the metaverse have provided valuable insights for researchers, but a bibliometric examination of the field is needed to generate additional insights about the impact of researchers and publications [49–56]. In this context, the authors of this article have utilized a bibliometric network analysis and topic modeling to explore the overall structure of the metaverse knowledge domain and the connection between metaverse-related works. This study makes three significant contributions to existing knowledge. Firstly, this is an examination of the metaverse literature since its inception, which expands the research on VR/AR and immersive digital environments [43,57]. As the concept of the metaverse continues to gain traction in popular culture and technological development, understanding the dynamics and structure of academic papers dealing with this topic contributes to the current body of knowledge on virtual worlds and their potential impacts on society. Secondly, this study of the metaverse literature sheds light on the technological, social, and ethical challenges that need to be addressed as we move toward a more immersive digital future. Finally, by conducting a bibliometric analysis of scholarly, metaverse-related articles, this study expands the field of bibliometric research. The exploration of the connections between different research works and the identification of key authors and journals in the field provides valuable insights for researchers and policymakers interested in the development of the metaverse. More specifically, we answer the following research questions:

- How has research on the metaverse evolved since its emergence in academia?
- What are the current research themes and knowledge structures in the selected metaverse publications, and what is the relationship among the various concepts studied by scholars?
- Who are the most influential authors and studies in the field of the metaverse?
- Which scholars and academic institutions have engaged in the most significant levels of collaboration within the metaverse domain?

The structure of this review is as follows. In Section 2, a four-step method for applying bibliometric analysis is described. Section 3 presents the research results, followed by Section 4, which proposes various directions for future research based on the findings of the bibliometric analysis. Lastly, Section 5 discusses the research findings, their implications, and their limitations.

2. Methodology

This bibliometric analysis used a four-step approach [58]. First, we specified the search database and keywords. Next, we conducted a preliminary analysis of the data, followed by an analysis of bibliometric networks. Finally, we performed a thematic analysis and conceptual structure analysis. To facilitate these analyses, we used various tools, such as the R software, bibliometrix, ggplot2, rentrez, and wordcloud. We also used VOSviewer, a computer program known for its ability to combine text mining techniques and visualization, allowing for the efficient management of network visualizations.

2.1. Database Selection and Search Keywords Identification

To gather all publications dealing with the metaverse, we used Scopus, a scientific database that contains citations and abstracts of peer-reviewed publications, including journal articles and conference proceedings [59]. Scopus is popular with academics for achieving high-quality analyses because of its user-friendly features that make performing bibliometric analyses easier [60]. Owned by Elsevier, Scopus is often regarded as the most comprehensive scientific database, surpassing even the Web of Science (WoS) and PubMed. In terms of coverage, Scopus contains 84% of the titles indexed in the WoS, whereas the WoS covers 54% of Scopus titles [54]. Scopus' better management of cited works and curated indexing makes it also more reliable than Google Scholar [61]. We collected the names of authors, titles of publications, academic journals, article types, abstracts, affiliations of authors, and the identifiers (ID) of all articles. The retrieved data were transferred to a CSV file for ease of subsequent investigation. Following the recommendations of prior studies [36,62,63], we used the search terms "meta-verse*", "metaverse*", and "meta verse*" in the Scopus title, abstract, and keywords fields to retrieve relevant data. We were able to collect a reasonable volume of articles for human review thanks to this search string, and the risk of generating false positive results owing to irrelevant terms was significantly decreased. Only English-language journal articles and reviews were considered for inclusion to obtain certified and comparable knowledge [64]. Although this approach might be viewed as restrictive, it was intentionally designed to maintain a level of scholarly rigor and reliability. On 1 March 2023, we ran the search and found 755 documents. We eliminated 160 articles after reading their titles and abstracts to determine whether they were relevant to our study or not. This process resulted in a final sample of 595 articles that were analyzed in detail.

2.2. Initial Analysis of the Selected Publications

We downloaded a BibTeX version of all articles' metadata, including the names of authors and titles, abstracts, and keywords of the selected articles, to perform a preliminary analysis of the literature sample. Table 1 summarizes the important data on the publications used for this analysis. The data in the table show that the collaboration index was 3.78. Based on the work of Price [65], Ajiferuke et al. [66] introduced the collaboration index as a novel statistic for fractional productivity. A low value for this index suggests that most of the publications cited are produced by a single author. In the metaverse context, collaboration among researchers is relatively high. This could be an indicator of a multidisciplinary approach to research, where researchers from different fields, such as computer science, psychology, and sociology, collaborate to explore the various aspects of the metaverse [3,67]. Overall, a collaboration index of 3.78 indicates that metaverse research is likely a collaborative effort among scholars, potentially leading to more comprehensive and diverse research outcomes.

Table 1. Main information about the literature sample.

Description	Results
Main information about data	
Timespan	2005:2023
Sources (e.g., journals, books)	318
Documents	595
Average years from publication	1.38
Average citations per document	7.262
Average citations per year per document	2.81
Document types	
Article	532
Review	63
Document contents	
Keywords plus (ID)	2431
Author's keywords (DE)	1771
Authors	
Authors	1900
Author appearances	2201
Authors of single-authored documents	116
Authors of multi-authored documents	1795
Author collaboration	
Single-authored documents	123
Documents per author	0.313
Authors per document	2.8
Co-authors per documents	3.7
Collaboration index	3.78

2.3. Social Network Analysis

Social network analysis (SNA), which involves the use of multidisciplinary techniques, such as mathematics, computer science, and statistics, is commonly used to examine complex networks. This approach has rapidly gained popularity as a formal analysis technique that can be used to identify hidden patterns and aid in theory development as well as to identify future research directions [54]. In this article, we relied on three important SNA metrics, including network size, density, and diameter [68]. In academia, SNA methods have been widely used, with many studies focusing on co-citations [69,70]. According to Li et al. [71], the knowledge base and research trends of a specified field can be exposed with the help of co-citation networks, which are composed of two articles concurrently cited in a third article. When comparing the semantic similarities of different articles or authors, co-citation networks are very helpful [72]. Changes in a field's prevailing paradigm can be uncovered by looking at the patterns of co-citations over time [73]. Moreover, the knowledge structure of a field can be exposed through the analysis of source co-citation networks, as noted by Ji et al. [74]. As such, source co-citation networks can be used to visually represent the knowledge patterns that suggest similarities across academic journals, such as methodological approaches and research scope. Collaboration networks are commonly used in bibliometric investigations [75] as a useful tool for graphically representing connections between scholars, academic institutions, and countries. These networks can also be used to show co-authorship relationships among researchers, academic organizations, or countries, which can indicate international collaboration [72]. According to Zou et al. [76], collaborative research efforts can lead to research innovation, high research quality, knowledge diffusion, and other mutual benefits. Additionally, Glänzel and Schubert [77] argued that multi-authored articles are more frequently published in impactful journals and receive more citations compared to single-authored articles. Ding [78] demonstrates that collaboration between academic institutions can promote research partnerships, ultimately aiding policymaking efforts. Additionally, scholars can use keyword co-occurrence networks to identify the core research content or thematic areas in a specific knowledge domain [55]. To further understand how the metaverse field has evolved, researchers can use this powerful data mining approach [79]. In a keyword co-occurrence network, each keyword is represented by a node, and the cluster to which it belongs is indicated by the node's color. The node size represents the keyword's occurrence frequency, and the edge's thickness represents the significance of the relationship between the two keywords.

2.4. Thematic and Conceptual Structure Maps

Strategic and thematic maps are based on the centrality and density metrics developed by Callon et al. [80]. Researchers can use these maps, which were first presented by Law et al. [81], to delve further into topics identified by frequently used keywords. According to Zong [82], the process of making these maps drew inspiration from keyword co-occurrence networks and financial portfolio analyses. Thematic maps excel at distinguishing between the centrality and density of studies across many categories. Density denotes the development of a subject, while centrality reflects the breadth of the interconnection between subjects [83]. Thematic maps can be created by clustering frequently used keywords, making it possible to derive more objective insights than can be gained by using only the conceptual structure map [84]. The use of thematic maps can quickly identify core themes and set the stage for further inquiry across several categories [85]. In academic research, these maps have seen extensive usage [30,72].

Conceptual structure maps offer an alternative approach to visualizing knowledge. These maps can be used to break down a scientific field into different research clusters by displaying keywords as points on the map, and the proximity of the points relative to one another indicates the frequency of articles discussing the related concepts. Points that are closer together indicate that more literature has been published on the topic, while points that are farther apart signal that less literature has been published. As pointed out by Cobo et al. [86], using these maps makes it easy to spot citation bursts for specific keywords and identify research trends. Through conceptual structure maps, researchers can better comprehend the most popular topics in the metaverse field.

3. Results

3.1. Academic Output, Relevant Journals, and Influential Authors

Upon examining the dataset detailing the annual number of publications that address the metaverse, a distinct pattern of exponential growth emerges (see Figure 1). This trend is particularly pronounced from 2020 onwards, culminating in the most recent figures from March 2023. Initially, the data reveals a relatively modest increase in metaverse-related publications between 2005 and 2017, averaging 2.6 publications per year. This period was characterized by the nascent stages of metaverse research, with scholars and technologists beginning to explore the potential of virtual environments and their integration with the physical world [21,87,88]. The subsequent years, 2018 through 2020, evinced a modest but noticeable uptick in metaverse-related publications, averaging 3.3 publications per year. This acceleration is likely attributable to the emergence of VR and AR technologies, which facilitated more immersive and interactive experiences within the metaverse [89].

In 2021, the number of publications surged to 17, marking a substantial increase in scholarly interest. This spike may be ascribed to the growing ubiquity of the metaverse as a concept, spurred by high-profile investments in virtual infrastructure and the advent of sophisticated platforms for social interaction and commerce [45,90]. However, it is the period from 2021 to 2023 that truly exemplifies a burgeoning fascination with the metaverse. In 2022, the number of publications skyrocketed to 362, representing a staggering 2188% increase from the previous year. The first quarter of 2023 alone witnessed 172 publications, which clearly indicates that the exponential trajectory is poised to continue. This unprecedented growth in metaverse-related research underscores the concept's increasing prominence in both academia and industry. This burgeoning interest can be attributed to several factors, including technological advancements, the proliferation of virtual economies, and the impact of global events such as the COVID-19 pandemic, which accelerated the adoption of virtual experiences [91–93]. Overall, the data reflects a rapidly evolving academic landscape characterized by an exponential surge in metaverse-related publications.

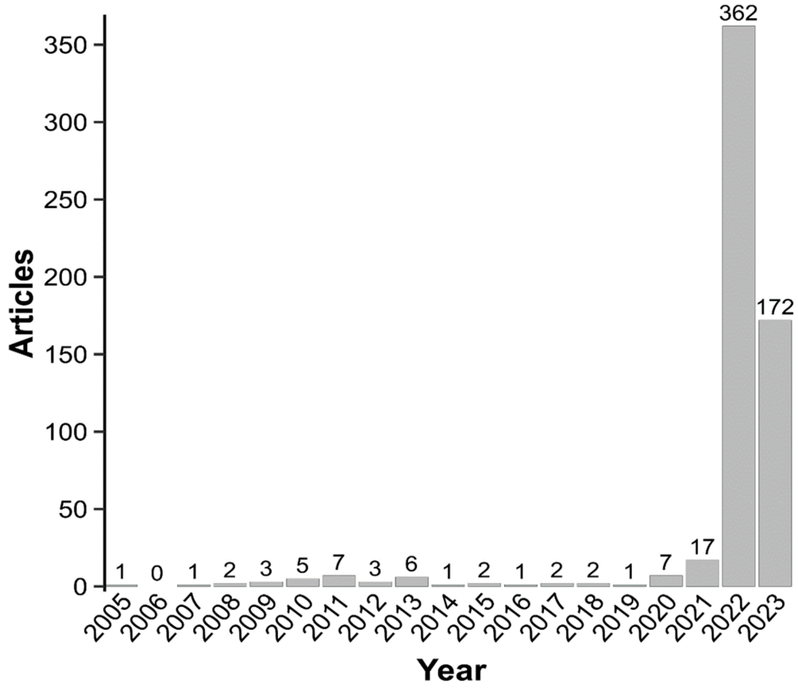

Figure 1. Annual number of publications dealing with the metaverse (until March 2023).

Figure 2 shows a word cloud of the most influential journals publishing academic articles on the metaverse, where the magnitude of the label matches the number of citations. Foremost among these publications is *the Journal of the Association for Information Systems*, which boasts an impressive 287 citations, indicative of its pivotal role in disseminating knowledge pertinent to the intersection of metaverse and information systems research. Closely following are *ACM Computing Surveys* and *IEEE Access*, with 220 and 253 citations, respectively. These journals are renowned for their contributions to the computing and engineering disciplines and have evidently expanded their scope to encompass the nascent metaverse domain, further demonstrating the multifaceted nature of this field. The *Technological Forecasting and Social Change* journal, amassing 125 citations, reflects a growing interest in understanding the societal implications and future developments of metaverse technology. Similarly, the *International Journal of Information Management*, with 176 citations, underscores the importance of managing information within the context of the metaverse, given its complex and rapidly evolving nature. References to the *Journal of Educational Evaluation for Health Professions*, with 126 citations, reveal the potential of metaverse research in revolutionizing educational practices and assessment methodologies, particularly within health professions. This highlights the transformative capacity of the metaverse in areas beyond entertainment and communication. Lastly, the *Journal of Marketing Management* and the *Electronic Commerce Research* journal, accumulating 97 and 96 citations, respectively, exemplify the commercial implications and economic opportunities stemming from the metaverse. These publications showcase a burgeoning interest in leveraging the metaverse to bolster marketing strategies and facilitate novel electronic commerce paradigms.

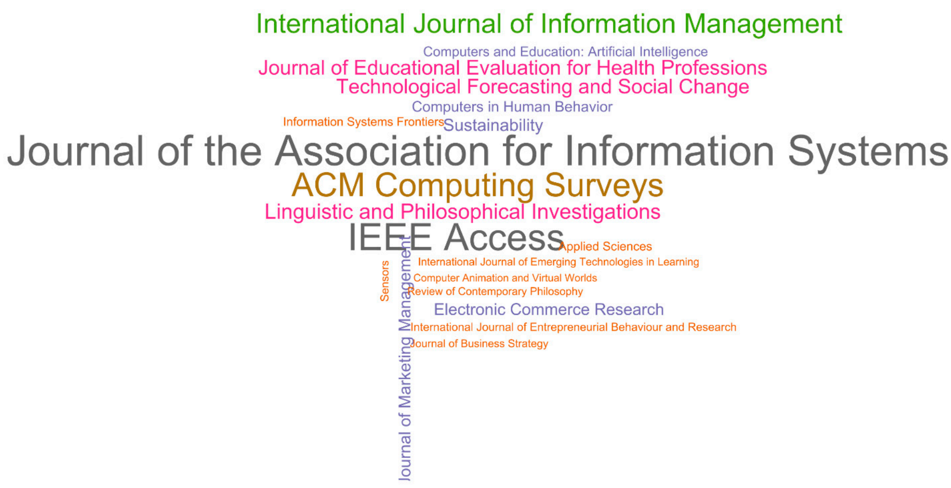

Figure 2. Word cloud of the most impactful journals publishing metaverse research.

Bradford's law can be used to evaluate scholarly output, as stated by Kumar and Dora [94]. This law originates from the necessity of identifying pertinent journals that release articles related to a subject matter during a certain research period [95]. As per the law: [...] if scientific journals are arranged in order of decreasing productivity of articles on a given subject, they may be divided into a nucleus of periodicals more particularly devoted to the subject and several groups or zones containing the same number of articles as the nucleus [96] (p. 85).

Figure 3 shows the distribution of academic articles on the metaverse across the first Bradford zone. This central zone, which comprises the top-tier journals, consists mainly of eight academic journals that publish the majority of articles on metaverse research. The figure demonstrates an inverse relationship between the number of journals and the frequency of citations received. It shows that only a few top-tier journals publish the majority of research articles in the metaverse field (Table 2). This figure can assist researchers in identifying the most productive journals in their area of interest.

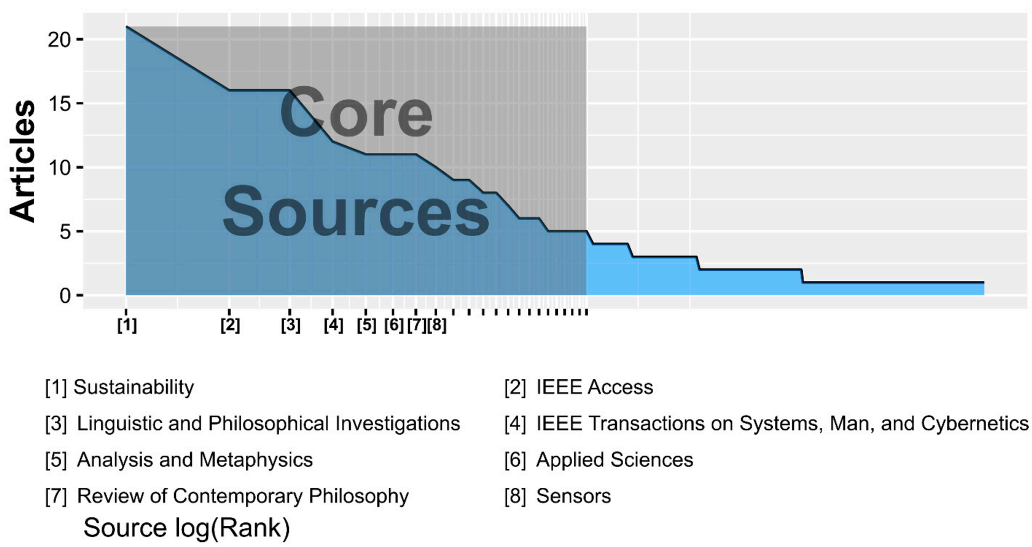

Figure 3. Distribution of journal articles on the metaverse across the core Bradford zone.

Table 2. Most productive journals in the metaverse field.

Journal	No. of Articles
Sustainability	21
IEEE Access	16
Linguistic and Philosophical Investigations	16
IEEE Transactions on Systems, Man, and Cybernetics: Systems	12
Analysis and Metaphysics	11
Applied Sciences	11
Review of Contemporary Philosophy	11
Sensors	10
Others (310 journals)	487

Figure 4 highlights the most productive authors in metaverse research, with a focus on the number of publications they have produced. Most of the authors started publishing on the topic in 2022, except for Papagiannidis, who published on the subject as early as 2008 [67]. This indicates that the field is a relatively new area of research. This finding aligns with the growing interest in VR and AR technologies, which have led to the development of the metaverse concept. The top three authors in the list, Dusit (Tao) Niyato (Nanyang Technological University), Fei-Yue Wang (Chinese Academy of Sciences), and Zehui Xiong (Singapore University of Technology and Design), have the highest number of publications, with 14, 12, and 12, respectively. Their work has contributed significantly to advancing knowledge on the metaverse. Jiawen Kang (Guangdong University of Technology), Dimitrios Buhalis (Bournemouth University), Chunyan Miao (Nanyang Technological University), Xuemin (Sherman) Shen (University of Waterloo), Yonglin Tian (Chinese Academy of Sciences), Nir Kshetri (University of North Carolina), Zihan Lv (Uppsala Universitet), and Savvas Papagiannidis (Newcastle University) follow the top three, with 8, 6, 6, 6, 6, 5, 5, and 5 publications, respectively. The inclusion of Papagiannidis, who published on the topic in 2008, suggests that the concept of the metaverse has been in existence for some time.

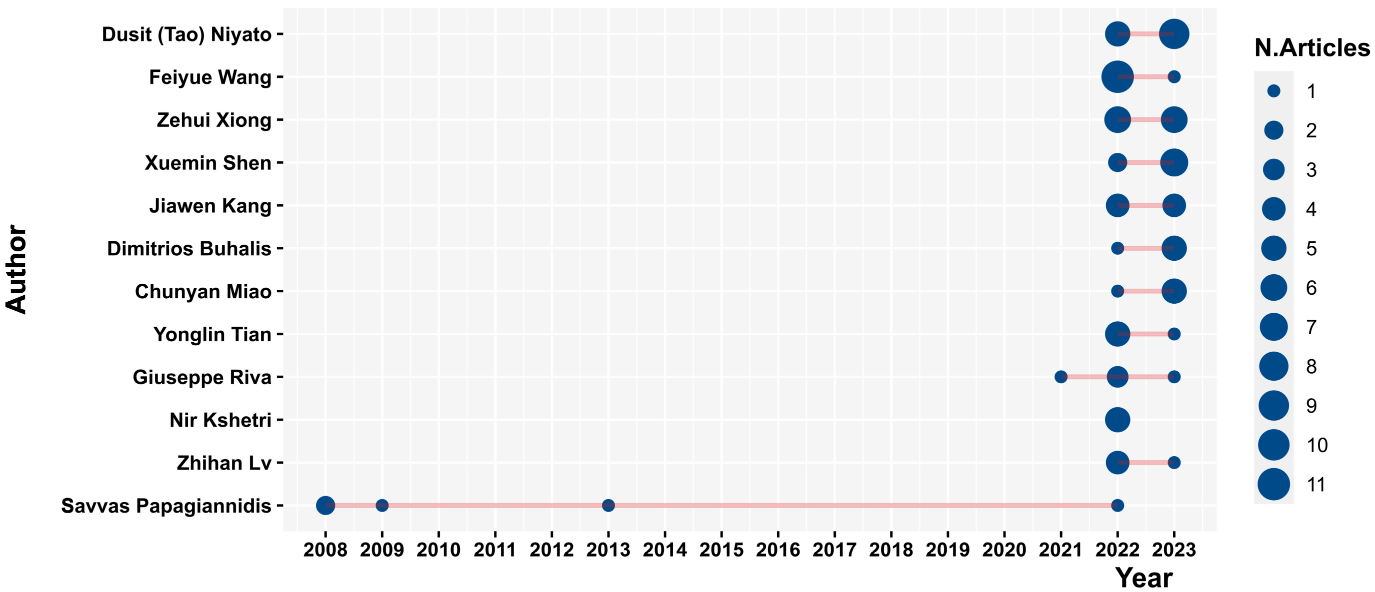

Figure 4. Most productive authors in metaverse research.

In the current investigation, we used Lotka's law to quantify the relative concentration of metaverse contributors [97]. Lotka's law states that, in cases where authors are ranked based on their number of articles, the number of authors publishing n articles should be proportional to 1/2n [98]. In simpler terms, Lotka's law proposes a negative correlation between the number of authors and their productivity in terms of publications, meaning that fewer authors tend to produce a greater number of publications, while the majority of authors produce only a few publications [99]. Lotka's law was applied to the metaverse literature using the bibliometrix R package, and the resultant distribution is shown in Figure 5. There are no statistically significant differences between the theoretical and empirical distributions, as determined using the Kolmogorov–Smirnov two-sample test at the conventional 0.05 level of significance. In addition, the extended tail in Figure 5, representing authors who have published only one article, indicates that most scholars might have explored the metaverse as a peripheral research topic [31].

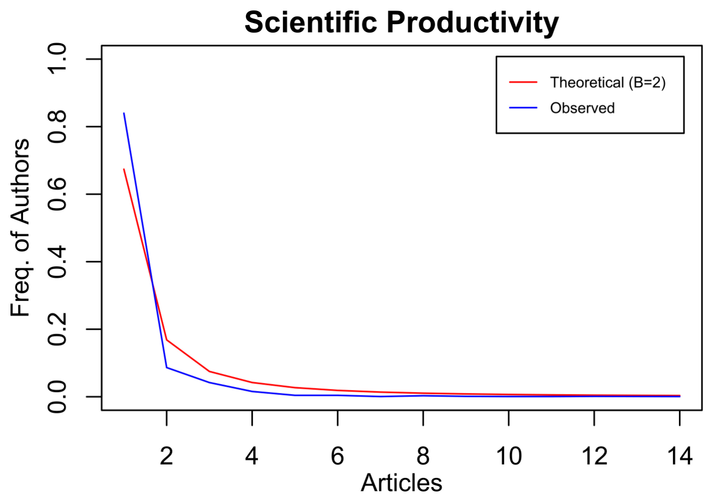

Figure 5. Lotka's law in metaverse research.

3.2. Network Analysis

3.2.1. Collaboration Networks

The authors' collaborative network in the metaverse field is shown in Figure 6, which has a size of 30, a density of 0.809, and a diameter of 1. The network data suggests that cooperation among authors is not very strong. This figure illustrates a small number of tightly connected scholarly communities that are identified by their distinct colors. Overall, the network is fragmented, indicating the research community in the metaverse field is not well integrated yet. Instead, it is characterized by pockets of collaboration, with limited cross-pollination and information exchange between these clusters. The low density of the network suggests that there are numerous potential connections between researchers that remain unexplored, leaving room for further collaboration and interdisciplinary research. However, the fragmentation of the network signals a lack of cohesion and may hinder the rapid development and dissemination of knowledge within the metaverse field. To foster a more connected and collaborative research environment, scholars in the metaverse domain should explore opportunities for interdisciplinary partnerships, and research institutions and funding agencies should support initiatives that encourage collaboration across different communities.

Additionally, Figure 7 illustrates the collaborative network among institutions in the metaverse field, which has a size, density, and diameter of 30, 0.908, and 2, respectively. In contrast to the authors' collaboration network, the institutional collaboration network appears more cohesive and interconnected, suggesting that institutions are actively forming partnerships and sharing resources to advance research in the metaverse field. The strong collaboration among institutions highlights the importance of fostering connections not only between individual authors but also between academic institutions. Such collaboration can facilitate the sharing of resources, expertise, and funding and ultimately accelerate the progress and development of the metaverse field.

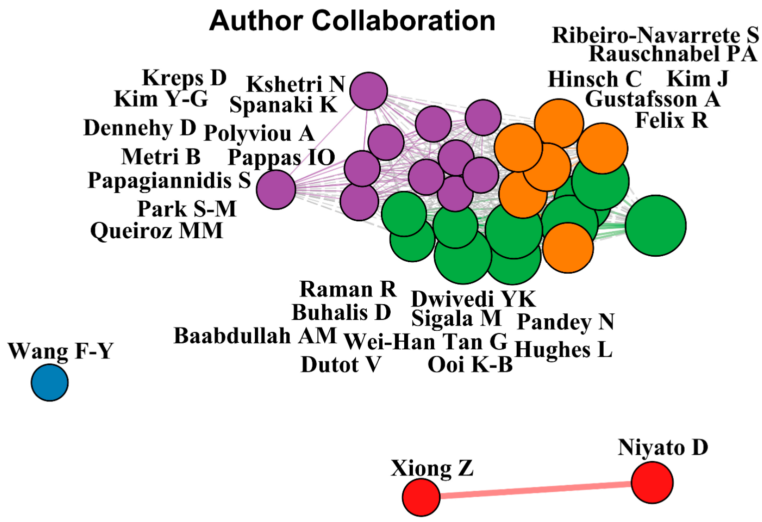

Figure 6. Authors' collaboration network in the metaverse field.

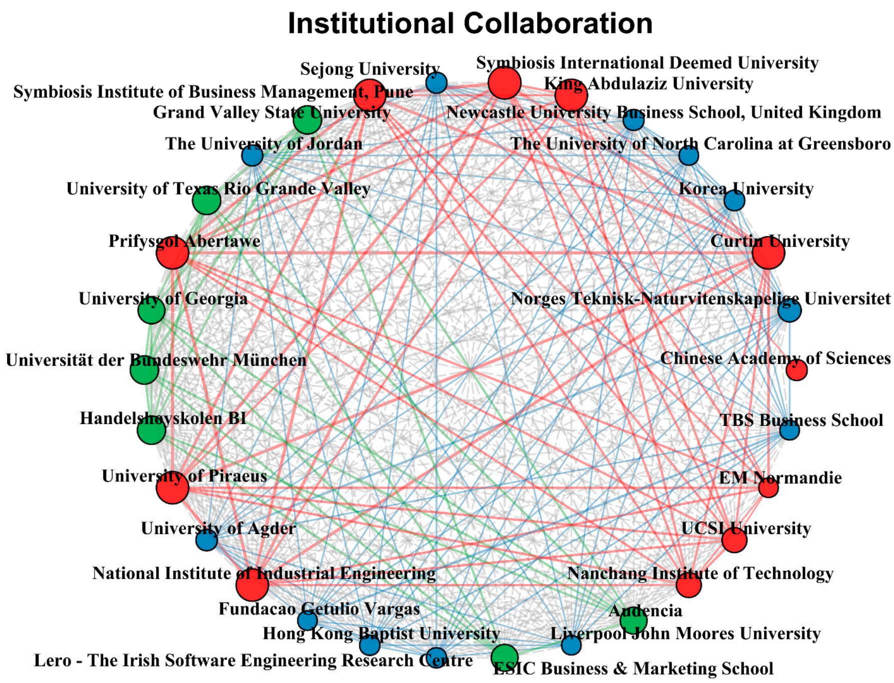

Figure 7. Institutional collaboration network in the metaverse field.

3.2.2. Keywords and Keyword Co-Occurrence Analysis

Keywords are crucial in understanding the core themes, trends, and focus areas within a particular research field [31]. They provide a glimpse into the most discussed topics, allowing researchers to identify prevalent issues and key concepts in the literature. By examining the frequency of specific terms in the abstracts of selected articles, we can obtain valuable insights into the current state of metaverse research and its future directions. The word cloud generated from the abstracts of selected articles in the metaverse field is depicted in Figure 8, revealing several dominant terms and concepts. For example, the high frequency of the keyword "virtual" highlights the strong emphasis on the virtual nature of the metaverse and its ability to create immersive digital environments [100]. This is further reinforced by the presence of the keyword "VR" (virtual reality), suggesting that VR technologies play a critical role in the development and exploration of metaverse environments [26,101,102].

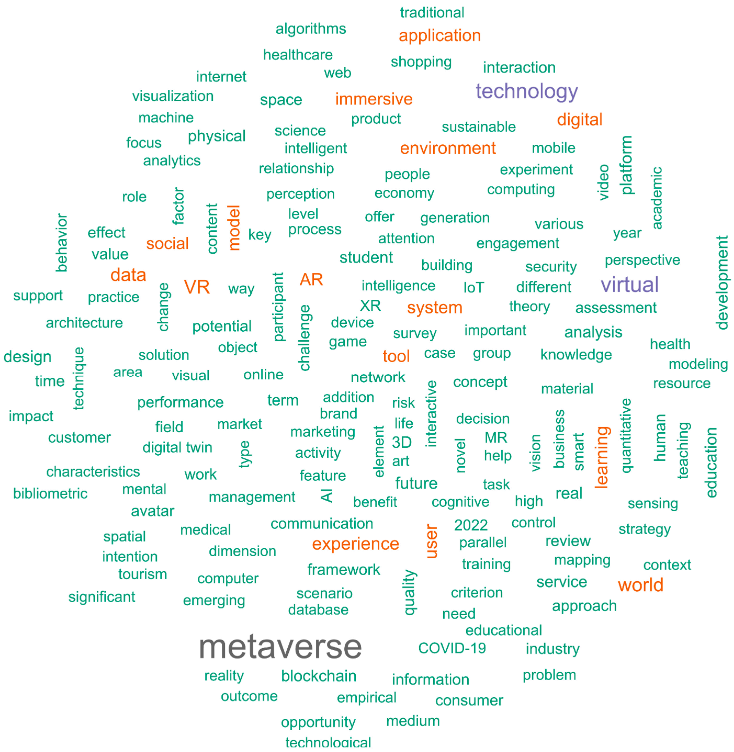

Figure 8. Word cloud of the most frequent terms in the abstracts of selected articles.

Figure 9 depicts the growth dynamics of keywords in the metaverse field, using the keywords field of all selected articles. The appearance of certain keywords with sudden bursts indicates emerging trends and priorities in metaverse research, as noted by Neff and Corley [103]. Examples of such keywords include VR, AR, XR, and blockchain. These keywords can also signify potential areas of interest or hotspots in metaverse research, as the body of knowledge in a particular academic field can be thought of as a series of ideas that emerge, gain prominence for a time, and eventually diminish [104].

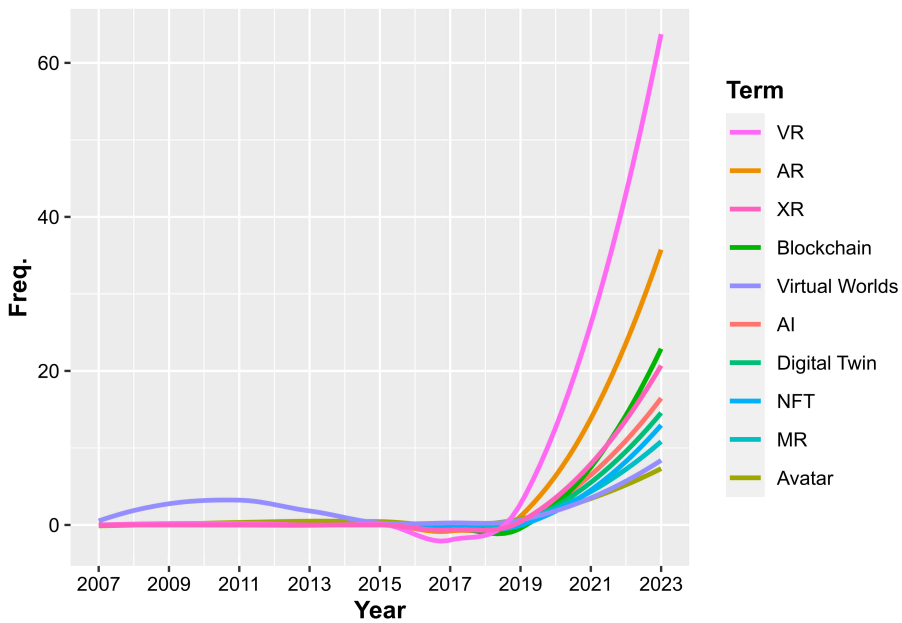

Figure 9. Growth dynamics of keywords in metaverse research.

This article generated a network of keywords that co-occur in the metaverse field, with a size, density, and diameter of 60, 0.224, and 2, respectively. Figure 10 depicts the generation of four distinct clusters by selecting the top 60 most commonly occurring keywords. It is apparent from the network that the red cluster is the most significant, as it contains the highest number of keywords. This cluster focuses on the intersection of immersive technologies, education, and the implications of the metaverse on the human experience [3,6,105]. This multifaceted concentration encompasses various dimensions, including the development and deployment of VR, AR, and MR technologies as well as the rise of XR as a unified framework [106,107]. The significance of virtual words and avatar-based platforms demonstrates the growing importance of creating and maintaining digital environments that foster collaboration and communication. According to several scholars [25,108,109], these digital spaces have gained prominence in response to the COVID-19 pandemic, necessitating new approaches to remote work [110], education [6,111–115], and social interaction [116]. Consequently, e-learning and technology-enhanced education [117] have emerged as critical areas of investigation, with a particular emphasis on gamification and the utilization of emerging technologies, such as deep learning and the fourth industrial revolution (4IR) paradigm [118]. For example, Hwang and Chien [119] argued that the metaverse contributes to education by offering diverse educational models and frameworks, enhancing learning performances and perceptions and providing innovative assessment approaches. It enables the development of metaverse-based environments for different educational purposes, expanding learners' opportunities and allowing them to participate in high-cost or high-risk programs. Moreover, the metaverse facilitates more accurate evaluations of learners' competencies and enables assessments that may be risky or impractical in the real world. The metaverse can also benefit students in learner-centered education and may help narrow the gender gap in the technology sector [120]. Furthermore, the findings of the cluster highlight the criticality of examining ethical, mental health, and sustainability aspects of the metaverse [121]. These considerations are particularly relevant in the context of human–computer interaction (HCI), embodiment, and consumer behavior [122]. The network also underscores the role of the metaverse in contemporary marketing, customer experience, and communication strategies, with a focus on eliciting emotions and shaping user experience [123].

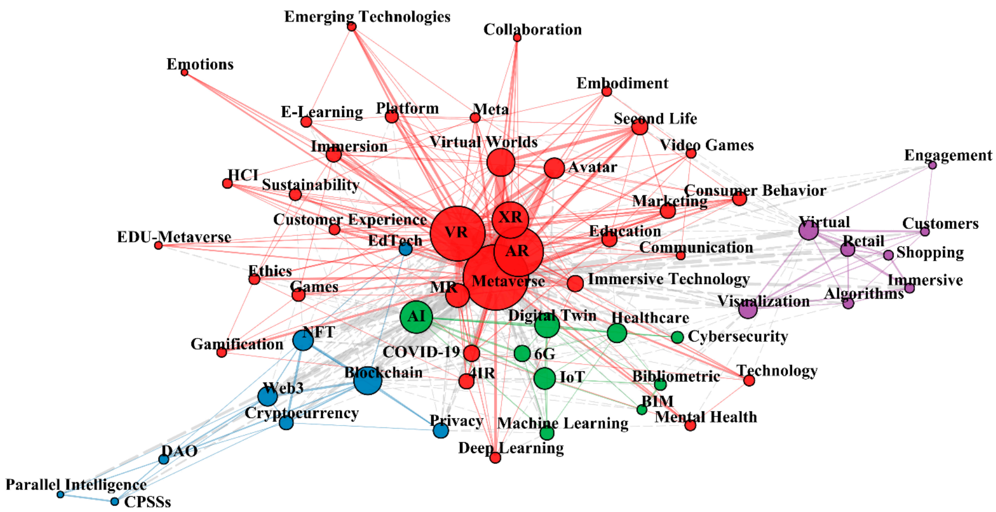

Figure 10. Keyword co-occurrence network in metaverse research.

An analysis of the second cluster (blue) unveils a core concentration on the convergence of decentralized technologies, digital assets, and novel paradigms for education and governance. This confluence of themes accentuates the transformative potential of the metaverse and its capacity to reshape existing societal and technological systems [124]. Foremost among the cluster's keywords are blockchain, NFTs (non-fungible tokens), and cryptocurrency, which collectively epitomize the growing significance of decentralized digital assets within the metaverse ecosystem [110,125,126]. These technologies enable the secure and transparent exchange of value, fostering novel economic systems and empowering users with a greater control over their digital assets. Complementing this focus on decentralization are the concepts of Web3, privacy, and parallel intelligence [127–129]. As a decentralized iteration of the internet, Web3 emphasizes the importance of user autonomy and data privacy [130,131], thereby addressing concerns regarding centralization and surveillance. Concurrently, parallel intelligence has emerged as a crucial area of inquiry, encapsulating the intersection of AI and blockchain technology and fostering innovative and collaborative problem-solving approaches [129]. In addition, the cluster emphasizes the increasing relevance of cyber–physical–social systems (CPSSs) and decentralized autonomous organizations (DAOs) within the metaverse [127,132]. Han et al. [127] noted that CPSSs can integrate digital and physical spaces and support synergistic interactions between human and technological agents. Wang [129] argued that DOAs represent a novel paradigm for governance that leverages smart contracts and consensus mechanisms to facilitate decentralized decision making and resource allocation. Finally, the inclusion of EdTech in the cluster alludes to the transformative potential of the metaverse for educational practices. By incorporating decentralized technologies and digital assets, new educational models and platforms can be developed, thereby promoting accessible, personalized, and equitable learning experiences [133].

The third cluster (green) focuses on the integration of advanced technologies, digital infrastructure, and their applications within various domains, such as healthcare and cybersecurity. The synthesis of the cluster accentuates the multidisciplinary nature of metaverse research and its capacity to influence a wide array of industries [110]. Central to the cluster are the keywords "AI" and "Machine Learning," which reflect the importance of intelligent systems and their potential to augment human capabilities within the metaverse [134,135]. These technologies have the potential to facilitate the creation of personalized experiences, enhance decision-making processes, and enable more efficient interactions between users and the digital environment. Scholars in this cluster also stress the role of digital twins and the IoT in shaping the metaverse landscape [136–138]. For example, Lv et al. [137] stated that digital twins provide a virtual representation of physical assets or processes, allowing for real-time monitoring, simulation, and optimization. In conjunction with IoT, these technologies enable the seamless integration of the physical and digital realms, paving the way for a more interconnected and data-driven metaverse ecosystem [136]. Similarly, the inclusion of 6G and BIM indicates the promising potential of cutting-edge digital infrastructure and its applications within the metaverse. The advent of 6G technology is expected to provide ultra-fast, low-latency connectivity, enhancing the overall user experience and enabling new use cases within the metaverse [139]. On the other hand, BIM focuses on the digital representation and management of built environments, which highlights the ability of the metaverse to revolutionize the architecture, engineering, and construction sectors. Within the third cluster, healthcare and cybersecurity emerge as crucial domains of scholarly interest. For instance, Chengoden et al. [11] noted that the metaverse has the potential to transform healthcare practices by providing immersive and personalized patient experiences, remote diagnostics, and telemedicine. Wang et al. [140] explored the integration of metaverse healthcare and suggested that the use of a metaverse platform can have significant impacts on clinical practice and human health, allowing for the development, evaluation, regulation, and refinement of AI-enabled medical practices, particularly in medical imaging-guided diagnosis and therapy. Mohamed et al. [141] synthesized the existing literature on the applications of the metaverse in e-healthcare and highlighted their role in reducing inequalities and delivering fair healthcare services. Similarly, Kim and Kim [142] investigated the applications of metaverse-based therapeutics in urology and underscored their potential to reduce healthcare costs, improve medical outcomes, and increase patient satisfaction. Ali et al. [143] argued that the metaverse can improve healthcare facilities and provide faster as well as more efficient and secure services with realistic experiences when AI and blockchain technologies are integrated. However, Chow et al. [144] posited that the increasing reliance on digital technologies raises concerns about data privacy and security, necessitating robust cybersecurity measures to ensure the protection of users and their information. Overall, the analysis of the third cluster highlights the potential for the metaverse to revolutionize various sectors while emphasizing the importance of a secure, interconnected, and intelligent digital ecosystem.

An examination of the fourth cluster (purple) reveals a primary focus on the nexus of immersive experiences, retail, and customer engagement within the metaverse field. This thematic concentration highlights the metaverse's revolutionary potential to shape new approaches to customer interaction, marketing, and service delivery in the retail sector [145]. At the core of this cluster are the notions of virtual and immersive experiences, which underlines the importance of designing digitally rendered environments that support user interaction and engagement [146]. According to Bourlakis et al. [27], these immersive experiences are enabled through advanced visualization techniques and algorithms, which work in concert to produce realistic, captivating, and interactive retail spaces within the metaverse. The cluster's emphasis on the commerce-driven aspects of the metaverse is shown by the prominence of retail and shopping as major keywords. The seamless integration of virtual retail spaces into the metaverse landscape offers novel opportunities for businesses to engage with customers and promote their products or services [110]. This innovative approach to retailing not only enhances the shopping experience but also fosters customer loyalty and satisfaction. Moreover, the keywords "customers" and "engagement" foreground the significance of understanding and catering to consumer preferences and behaviors within the metaverse [110]. By leveraging the immersive nature of virtual spaces, businesses can create personalized experiences that resonate with their target audiences and foster meaningful connections [147]. This focus on customer engagement also emphasizes the potential of the metaverse to cultivate enduring relationships between brands and consumers, transcending traditional barriers of physical space and distance. In summary, the final cluster accentuates the interplay of immersive experiences, retail, and customer engagement within metaverse research. This analysis highlights the promising capacity of the metaverse to reshape the retail industry and provide innovative, personalized experiences for consumers. By embracing the potential of this digital landscape, companies can forge deeper connections with their audiences and unlock new opportunities for growth and success.

3.3. Topic Modeling

Topic modeling is an indispensable tool in the field of text mining and natural language processing since it facilitates the discovery of hidden semantic structures within vast collections of documents [148]. By automatically identifying and categorizing underlying themes, topic modeling enables researchers to glean insights from large textual datasets, making it an essential technique for understanding and organizing the vast amounts of information available in the digital age [149]. Conceptually, topic modeling is a probabilistic, unsupervised machine learning technique used to discover abstract topics within a corpus of text documents. Through the analysis of the distribution of words and their co-occurrences, topic modeling algorithms can infer latent themes and group related documents accordingly. This powerful method has been applied to the investigation of a diverse array of fields, such as world trade, Industry 4.0, and public discourse during the COVID-19 pandemic, for purposes ranging from sentiment analysis to the identification of emerging trends [150–152]. In this study, latent Dirichlet allocation (LDA) has been chosen as the topic modeling technique for analyzing the abstracts of selected publications. LDA is a generative probabilistic model that assumes documents are composed of a mixture of topics, with each topic representing a distribution of words [153]. LDA operates on the premise that each document consists of a blend of several topics and aims to uncover these by examining word patterns and co-occurrences [154]. This approach allows for the systematic examination of large amounts of literature, offering a robust methodology for topic detection [155,156].

The initial steps of the analysis involved text preprocessing, removing irrelevant elements, and breaking down phrases into individual words using the Python library Gensim. We constructed an effective lexicon, which is crucial for deciphering themes from the texts. Subsequently, we used the Mallet toolset to construct the LDA model and determined the optimal number of topics using the topic coherence score [157]. This process revealed that a model with five topics provides the best balance for analysis (see Figure 11).

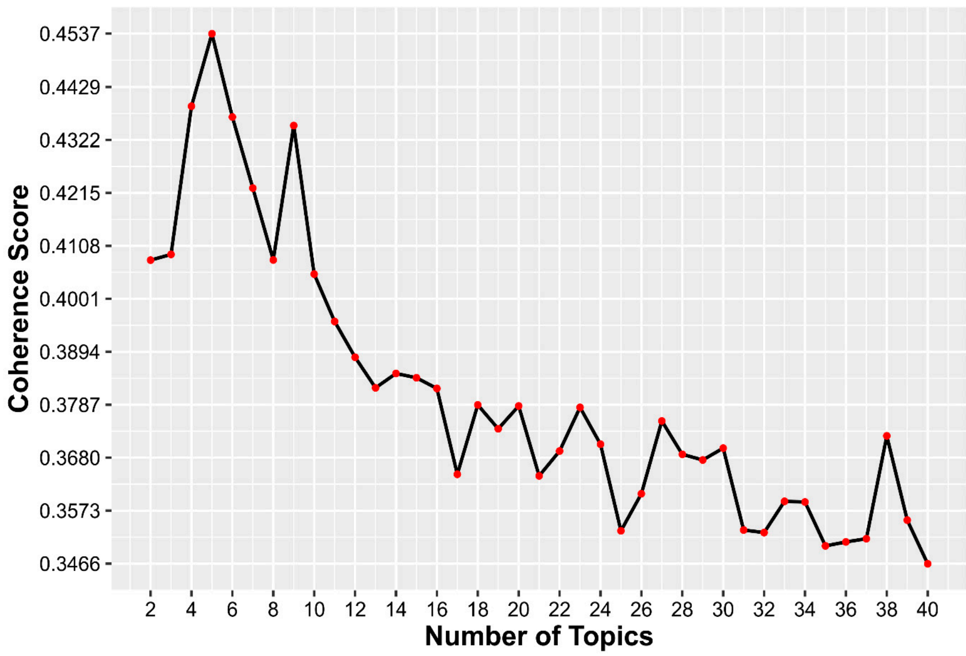

Figure 11. Inference of the optimum number of topics in metaverse research based on LDA.

The LDA model was used to identify how frequently the five topics were discussed in the selected articles. We quantified this using the semantic coherence approach and graphical tools, such as PyLDAvis and Matplotlib, for visual representation and analysis (see Table 3).

As shown in Figure 12, the LDA approach uncovered five major topics in the metaverse literature. The first topic covers the concept of the metaverse and its related technologies, including VR, blockchain, and AR. Additional keywords related to this topic include "digital", "sensing", and "application". This suggests that the first topic is focused on the technical and conceptual aspects of the metaverse and its potential applications and development.

The second topic revolves around the potential applications of the metaverse in education and learning. One salient aspect of this topic is the development of immersive learning environments, which harness the power of VR and AR technologies to create interactive 3D spaces [6]. These environments have the potential to enhance students' engagement, motivation, and overall learning outcomes by providing them with authentic, hands-on experiences that are unattainable within the confines of a traditional classroom [158]. According to Zhong et al. [115], the introduction of the metaverse into education will lead to a future of more intelligent, digitalized, and virtualized learning owing to its dynamic intelligence, comprehensive perception, and integration of virtual and real elements. Kaddoura and Husseiny [113] noted that virtual words offer new instructional approaches that foster active participation and visual imagery in the learning process. With its scalability and its interactive elements, the metaverse enables the implementation of teaching methods such as inverted classes and collaborative learning, promotes flexibility, and fosters positive classroom dynamics. Moreover, the metaverse can promote collaborative learning opportunities, enabling learners from diverse geographical locations to interact with one another in real-time [33]. This interconnectedness not only broadens students' cultural horizons but also fosters the development of essential soft skills, such as communication, teamwork, and problem-solving [159]. The metaverse also offers the prospect of personalized learning pathways and allows educators to tailor instructional materials and activities to meet the unique needs of individual learners [6].

Table 3. Value of coherence score per number of topics.

Number of Topics	Coherence Score	Number of Topics	Coherence Score
2	0.4079	22	0.3693
3	0.4091	23	0.3782
4	0.4390	24	0.3707
5	0.4537	25	0.3532
6	0.4368	26	0.3607
7	0.4225	27	0.3754
8	0.4079	28	0.3687
9	0.4351	29	0.3675
10	0.4051	30	0.3699
11	0.3955	31	0.3534
12	0.3883	32	0.3529
13	0.3821	33	0.3592
14	0.3850	34	0.3590
15	0.3841	35	0.3502
16	0.3820	36	0.3510
17	0.3646	37	0.3516
18	0.3787	38	0.3724
19	0.3738	39	0.3554
20	0.3785	40	0.3466
21	0.3643		

The third topic focuses on the role of the metaverse in healthcare and its impact on human wellbeing. More specifically, the metaverse can be used to support telemedicine applications and remote patient care [26]. Through the creation of immersive, interactive, and collaborative environments, healthcare professionals can virtually assess, diagnose, and treat patients from a distance, thereby surmounting geographical barriers and enhancing access to quality healthcare services for individuals in remote or underserved regions [11]. According to Bansal et al. [26], the metaverse holds considerable promise in the realm of medical education and training. Medical professionals can leverage the power of VR and AR technologies to partake in realistic simulations that replicate various clinical scenarios and foster the development of essential skills and competencies in a safe and controlled environment. As a result, this experiential learning approach can expedite the process of knowledge acquisition and skill development, eventually leading to improved patient outcomes.

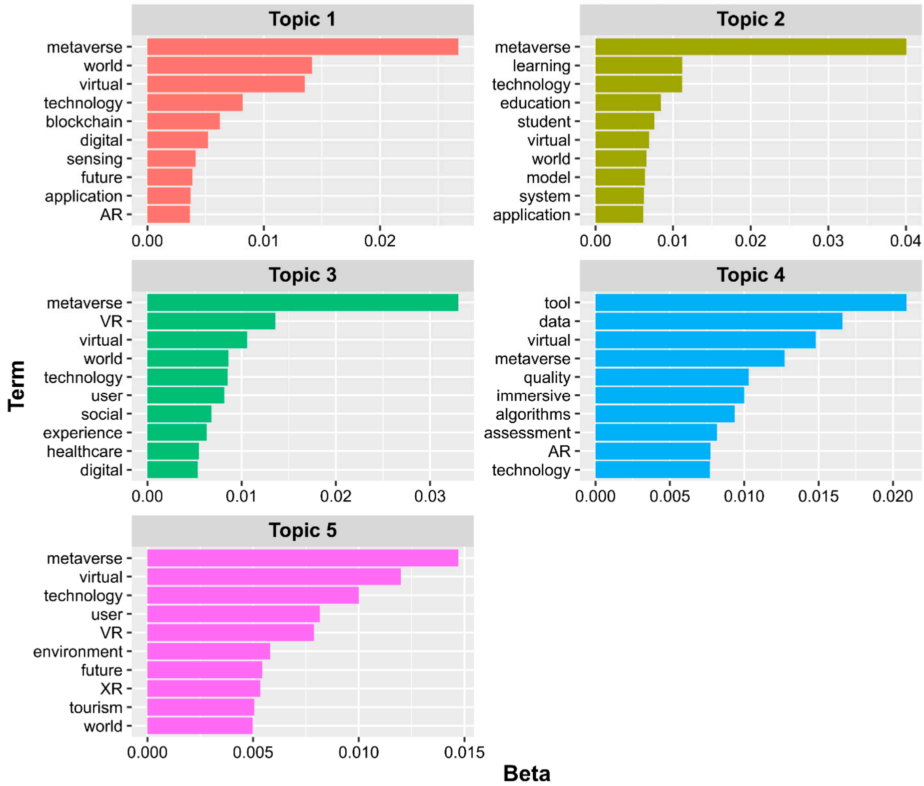

Figure 12. Metaverse topic modeling using the LDA approach.

The fourth topic accentuates the employment of the metaverse as a potent instrument for data analytics, consumer behavior analysis, and visualization. This burgeoning area of research explores the myriad ways in which the metaverse can transform the fields of marketing, consumer research, and business intelligence by leveraging the power of VR, AR, artificial intelligence (AI), and machine learning (ML) technologies [160,161]. The metaverse can be used as a platform for studying and understanding consumer behavior within immersive, interactive environments [27]. Researchers can replicate realistic marketplaces and consumer scenarios to glean valuable insights into consumer preferences, decision-making processes, and emotional responses [145]. This can, ultimately, inform more effective marketing and advertising strategies. Furthermore, the metaverse enables organizations to capture granular, real-time data on consumer interactions, movements, and transactions, thereby providing unprecedented access to rich, contextualized data sets. The integration of AI and ML algorithms facilitates the analysis of this wealth of data, empowering businesses to identify emerging trends, detect patterns, and predict future consumer behavior with greater accuracy and precision [161].

The fifth topic pertains to the exploration of the metaverse's applications in the tourism and hospitality industries. The development of virtual tourism through the metaverse facilitates users' exploration of and engagement with authentic, 3D representations of destinations and attractions [162]. This innovative approach enables travelers to preview and meticulously plan their trips and offers an accessible and environmentally sustainable alternative for individuals constrained by mobility and financial limitations [163]. Moreover, the metaverse presents unique opportunities for the preservation and promotion of cultural heritage [100]. By digitally archiving and reconstructing historical sites, artifacts, and intangible cultural expressions, the metaverse fosters a more profound understanding and application of diverse cultures, thus facilitating cross-cultural exchange and empathy [164]. Within the hospitality sector, the metaverse holds considerable promise for enhancing customer service and personalizing guest experiences [162]. Hotels and resorts can incorporate AI-powered chatbots and virtual concierge services to provide real-time assistance and bespoke recommendations to guests, which can ultimately improve satisfaction and engender loyalty. Moreover, the metaverse enables hospitality businesses to offer virtual previews and walkthroughs of their accommodations, empowering prospective guests to make more informed decisions and manage their expectations [165].

3.4. Conceptual Structure and Thematic Maps

In bibliometrics, a conceptual structure map serves as a visual representation of the intellectual landscape of a specific research area [68]. This map elucidates the underlying structure, relationships, and thematic patterns among various keywords and concepts, thereby facilitating a deeper understanding of the field's evolution, current state, and potential future trajectories. To generate this conceptual structure map, bibliometric data is extracted from the selected journal articles. Employing advanced text mining techniques and clustering algorithms, the extracted data is analyzed to identify salient keywords and concepts [68]. Subsequently, these identified elements are grouped into coherent clusters based on their interrelationships and co-occurrence patterns. According to Figure 13, three distinct clusters reveal the primary themes and intersections within the field. The red cluster, which represents the most important theme, encompasses keywords related to the core technologies and concepts underpinning the metaverse, such as VR, AR, MR, XR, digital twin, and immersive experiences. This cluster highlights the fundamental technological building blocks that enable the creation of immersive, interactive virtual worlds and avatars as well as the convergence of these technologies in the metaverse. The blue cluster encompasses keywords associated with the enabling technologies and contextual factors that shape the metaverse's development and adoption, including AI, IoT, blockchain, Web3, NFT, and COVID-19. This cluster signifies the increasing integration of advanced technologies to enhance the capabilities and functionalities of the metaverse as well as the role of contextual factors, such as the COVID-19 pandemic, in accelerating the shift toward digital and virtual experiences. Finally, the purple cluster contains keywords related to practical applications of the metaverse, particularly in the context of visualization and virtual retail. This cluster underscores the burgeoning interest in harnessing the metaverse to revolutionize various industries, including tourism, hospitality, and retail, by offering immersive and personalized experiences for consumers.

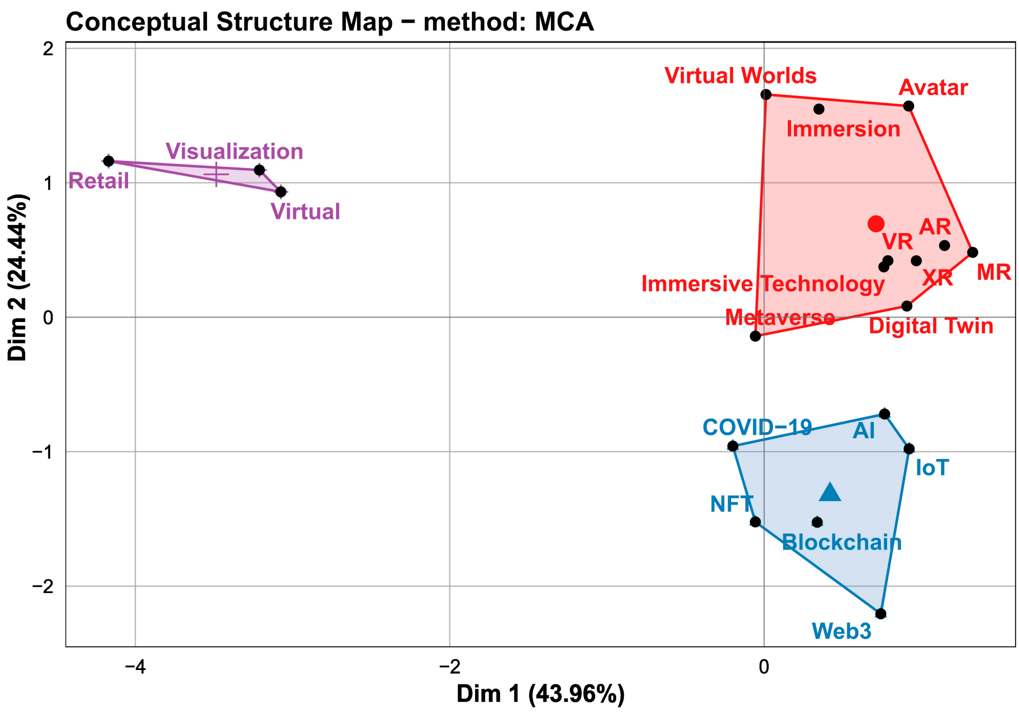

Figure 13. Conceptual structure map of metaverse research.

A thematic map is a visual representation of the intellectual structure and evolution of a specific field, capturing the interrelations and dynamics among various themes and concepts [30]. The size of the bubbles in the map is indicative of the prevalence and importance of the corresponding themes, while the color represents the distinct clusters that are formed based on their thematic similarity. The thematic map is divided into four quadrants, each representing a distinct category of themes (see Figure 14). The niche themes quadrant encompasses specialized yet less prevalent research areas. In the case of metaverse research, this quadrant contains two bubbles: one representing "computational modeling" and "data models", highlighting the importance of data-driven approaches in the development and analysis of the metaverse, and a second bubble comprising "parallel intelligence", "CPSSs", "DAOs", and "industrial metaverse", emphasizing the integration of advanced technologies and systems to enhance the metaverse's capabilities in industrial applications. The motor themes quadrant represents well-established and influential research areas that drive the field's progress. In the metaverse research thematic map, this quadrant contains a single bubble that includes keywords such as "virtual", "retail", "visualization", "immersive", and "bibliometric". This signifies a focus on practical applications of the metaverse and the importance of bibliometric analysis in understanding the field's intellectual structure. The basic themes quadrant encompasses fundamental and core research areas that form the foundation of the field. The first bubble in this case includes keywords such as "virtual worlds", "avatar", "second life", "immersion", and "education". These keywords highlight the historical development of virtual environments and their applications in education. The second bubble, comprising "metaverse", "VR", "AR", "XR", and "blockchain", underscores the key technologies that underpin the metaverse and enable the convergence of immersive experiences. Lastly, the emerging or declining themes quadrant captures research areas that are either gaining momentum or losing relevance over time. This quadrant contains a single bubble with keywords such as "technology", "platform", "Meta", "Facebook", and "governance". This cluster highlights the growing influence of technology companies, such as Facebook (now Meta), in shaping the metaverse's development and the importance of addressing governance issues related to privacy, security, and ethical concerns.

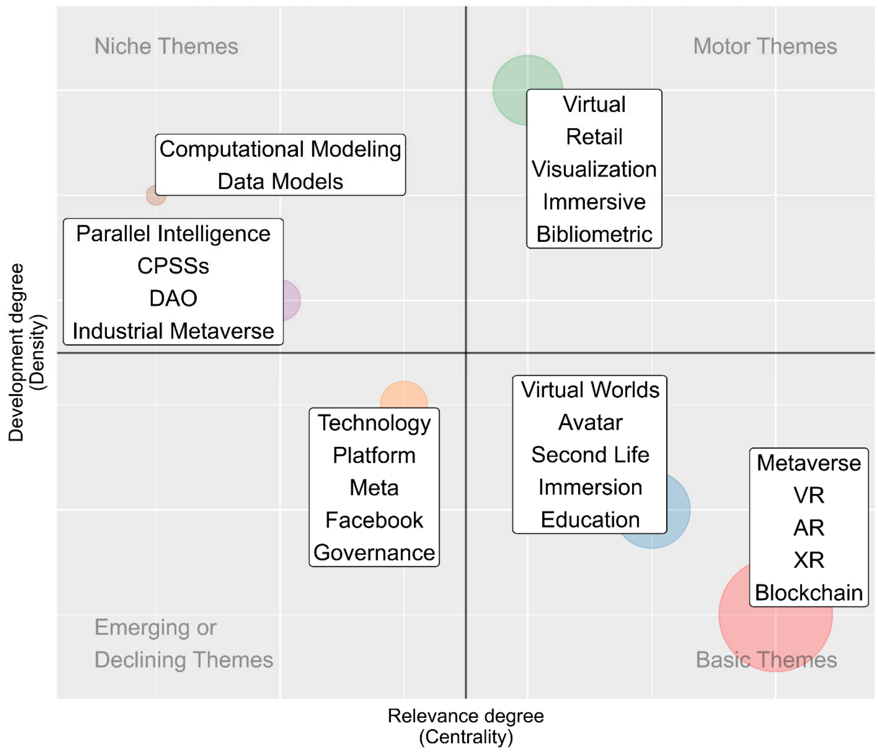

Figure 14. Thematic map in metaverse research.

4. Future Research Directions

Drawing from the results of the keyword co-occurrence network and topic modelling, this review puts forth several directions for future research:

- In light of the burgeoning interest in the metaverse and its associated technologies, there are numerous avenues for future research that warrant exploration. One such direction could involve a comprehensive examination of the convergence of VR, AR, and blockchain technologies within the metaverse framework [14]. Investigating the synergistic potential of these technologies, while also accounting for their ethical implications and societal impact, would make a significant contribution to the scholarly discourse surrounding the metaverse [133]. Moreover, scholars need to focus on the development and refinement of digital sensing technologies that underpin the immersive experiences within the metaverse [128]. These advancements, in turn, hold the potential to revolutionize the way users interact with digital environments and other users. As a result, delving into the optimization of these sensing technologies and their integration with the metaverse's infrastructure can provide valuable insights into the creation of more seamless and intuitive virtual experiences. As the metaverse becomes increasingly ubiquitous, it is crucial to examine the dynamics of power, control, and ownership within this digital realm [107]. A critical evaluation of the role of blockchain technology in ensuring decentralization, user autonomy, and data privacy could help illuminate the potential for more equitable governance structures in the metaverse. This line of research might also delve into the regulatory frameworks necessary to mitigate potential misuse and safeguard users' rights in the rapidly evolving metaverse landscape [166]. In sum, we suggest the following research questions:
    a. How can VR, AR, and blockchain be integrated within the metaverse framework?
    b. What are the ethical implications of the metaverse?
    c. What is the societal impact of the metaverse?
    d. How will digital sensing technologies shape users' experience of the metaverse?
    e. How will power, control, and ownership evolve in the metaverse?
    f. How can blockchain impact decentralization, user autonomy, and privacy in the metaverse?
    g. What regulatory frameworks are needed/appropriate for the metaverse?
- Related to the potential applications of the metaverse in education and learning, future research could involve the systematic evaluation of the efficacy of immersive learning environments, which leverage VR and AR technologies to engender interactive 3D spaces [6]. By examining the impact of these environments on student engagement, motivation, and learning outcomes, researchers can elucidate the advantages and limitations of integrating the metaverse into diverse educational settings. In addition, scholars might investigate the dynamics of virtual interaction among learners hailing from disparate geographical locations, paying particular attention to how these interactions cultivate essential soft skills. This research could also encompass the cultural dimensions of metaverse-enabled learning, examining how these virtual spaces foster cross-cultural understanding and promote global citizenship among students [167]. The metaverse's capacity for tailored instructional materials and activities offers a promising domain for further investigation into the personalization of learning pathways [168]. In this regard, researchers may delve into the efficacy of adaptive learning algorithms and data-driven approaches to customize educational content within the metaverse, including diverse aspects of personalized learning, such as balancing student autonomy and instructor guidance and addressing ethical considerations related to data privacy and algorithmic fairness [92]. Furthermore, future research might address the challenges and barriers to the widespread adoption of the metaverse in education. Investigating factors such as technological infrastructure, digital literacy, and accessibility can shed light on the disparities that may emerge in a metaverse-enabled learning landscape. The emerging research questions are as follows:

h. How efficient are immersive learning environments in the metaverse?
i. How does a metaverse environment influence student engagement, motivation, and learning outcomes?
j. How does the metaverse impact interactions between learners from different cultural backgrounds?
k. Can the metaverse contribute to the personalization of individual learning pathways?
l. What are the challenges and barriers to widespread metaverse adoption in education?

- The significance of the metaverse in healthcare and its potential impact on human well-being has been highlighted repeatedly in the academic literature. To advance research in this direction, researchers need to assess how the metaverse can overcome geographical barriers, improve access to quality healthcare services, and address the needs of individuals in remote or underserved regions [26]. Another research direction pertains to the development and evaluation of medical education and training within the metaverse. Future studies could also explore how a metaverse-enabled experiential learning approach can accelerate knowledge acquisition and skill development, ultimately contributing to improved patient outcomes [11]. Furthermore, researchers could explore how virtual therapeutic interventions may effectively treat mental health conditions, such as anxiety, depression, or post-traumatic stress disorder [35]. They can leverage the immersive and interactive nature of virtual environments in the metaverse to develop innovative interventions that promote relaxation, mindfulness, and overall wellbeing. Finally, investigations into issues such as data privacy, security, and informed consent can help inform the development of robust regulatory frameworks that protect patients' rights and ensure the responsible use of metaverse technologies in healthcare [26]. The following questions need to be answered:

m. What is the impact of the metaverse on healthcare?
n. How can the metaverse foster medical education and training?
o. Can the metaverse be applied in therapeutic interventions related to mental health conditions (including wellbeing in general)?
p. What regulatory frameworks are needed to protect patients' rights in the metaverse?

- An important area of investigation involves the exploration of the metaverse as a platform for studying consumer behavior within immersive, interactive environments [161]. Researchers could develop and evaluate methodologies for replicating realistic marketplaces and consumer scenarios, aiming to extract valuable insights into consumer preferences, decision-making processes, and emotional responses. These findings can ultimately inform the development of more effective marketing and advertising strategies that cater to the evolving needs and expectations of consumers. Moreover, future research might address the role of the metaverse in capturing granular, real-time data on consumer interactions, movements, and transactions. Scholars could investigate the challenges and opportunities associated with harnessing rich, contextualized datasets generated within the metaverse as well as the ethical implications surrounding data privacy and informed consent [169]. This line of inquiry can contribute to the development of best practices for data management and analysis within the metaverse. The integration of AI and ML algorithms in the metaverse context presents a further domain for exploration [161]. Researchers might investigate the effectiveness of these algorithms in analyzing the wealth of data generated within the metaverse, with a particular focus on identifying emerging trends, detecting patterns, and predicting future consumer behavior. Studies that assess the accuracy and precision of these algorithms as well as their potential biases and limitations can contribute to the refinement of data-driven decision-making in the realms of marketing and business intelligence [124]. We postulate the following research questions:

q. What theories/frameworks/methods are suitable for investigating consumer behavior in the metaverse?

r. How does the metaverse shape user preferences, decision-making processes, and emotional responses?
s. Which marketing strategies best utilize the idiosyncrasies of the metaverse?
t. How can metaverse data be used for marketing purposes?
u. What are the ethical and privacy-related consequences of the use of metaverse data?
v. How can AI and machine learning be used on metaverse data to identify emerging trends and predict future consumer behavior?

- Potential applications of the metaverse encompassing fields such as tourism, gaming, movies, and also metaverse creation tools, such as Unity, reveal several intriguing avenues for research. In the realm of gaming and movies, for instance, there exists a valuable opportunity to utilize popular digital media as portals to immersive travel experiences. Gaming landscapes could serve as innovative, interactive travel guides, while movies may offer virtual tours of locations in a more accessible and environmentally friendly manner, especially for people with mobility or financial limitations [169]. Meanwhile, metaverse creation tools such as Unity could be pivotal in digitally archiving and reconstructing historical sites, artifacts, and intangible cultural expressions. These technologies could stimulate a deeper understanding of diverse cultures, fostering cross-cultural exchange and empathy and, ultimately, enriching global tourism [122]. Within the hospitality sector, the metaverse is poised to revolutionize customer service and personalize guest experiences. By incorporating elements of gaming and a cinematic narrative into guest interactions, the industry could engage customers in an entirely new way. Moreover, AI-powered chatbots and virtual concierge services, potentially developed using tools such as Unity, could provide real-time assistance and tailored recommendations to guests. Further study of the impact of these technologies on guest satisfaction and loyalty is warranted. This research can elucidate how the metaverse can reshape the hospitality industry, leading to improved customer experiences. The following questions, encompassing these broader areas of the metaverse, need to be addressed:

w. How can gaming and movies within the metaverse provide environmentally friendly and easily accessible travel alternatives?
x. To what extent can historical sites, artifacts, and intangible cultural expressions be digitally archived and/or reconstructed in the metaverse?
y. How does the metaverse, through its diverse facets such as gaming, movies, and digital construction, impact cultural diversity and cross-cultural exchange in tourism?
z. How can the metaverse help to enhance customer service and personalize guest experiences, possibly through the incorporation of gaming and cinematic elements?
aa. How can AI-powered chatbots and virtual concierges impact the guest experience?

5. Conclusions, Implications, and Limitations

The purpose of this study was to analyze the current state of metaverse research using bibliometric and topic modeling techniques. In contrast to subjective methods, bibliometric analysis can provide an objective view of a scientific domain, as it avoids biases resulting from a selective choice of evidence [31]. The analysis included 595 metaverse-related journal articles published by 1900 scholars. This study is the first of its kind to investigate the bibliometric profile of metaverse research. The results reveal the major trends, prolific authors, and most active journals in the metaverse knowledge field. The findings indicate that the evolution of metaverse research has seen a distinct pattern of exponential growth since 2020, with a significant surge in publications in the last two years. The burgeoning fascination with the metaverse can be attributed to various factors, including technological breakthroughs, the proliferation of virtual economies, and the impact of the COVID-19 pandemic. In terms of journal influence, the metaverse field is still relatively new and rapidly evolving, with a small number of top-tier journals publishing the majority of academic articles. This highlights the need for more research and scholarship in this emerging field to expand the knowledge base and further advance the metaverse. The examination of the most productive authors in the literature suggests that the majority of them began publishing on this topic in 2022. The implementation of Lotka's law demonstrates that only a few authors produce the majority of articles, while many others only publish a few articles. The authors' collaborative network displays a lack of research cooperation, which may hinder the rapid dissemination and advancement of knowledge, while the institutional collaboration network exhibits more coherence and interconnectivity, underscoring the importance of promoting relationships between academic institutions to accelerate progress in the metaverse field.

In this research, a comprehensive keyword co-occurrence analysis was performed to discern distinct areas of interest within the rapidly evolving field of the metaverse. The analysis yielded four significant clusters of keywords, each revealing a unique facet of metaverse-related interests. The first cluster underscores the importance of immersive technologies, education, and the impact of the metaverse on the human experience. Within this cluster, virtual worlds, e-learning, and ethical, mental health, and sustainability considerations emerged as critical aspects that require further examination and understanding. The second cluster concentrates on the amalgamation of decentralized technologies, digital assets, and innovative approaches to education and governance. Keywords such as blockchain, artificial intelligence, and cryptocurrency signify the metaverse's potential to radically transform societal and technological systems. The third cluster accentuates the incorporation of advanced technologies and digital infrastructure across various domains, including healthcare and cybersecurity. The network pinpoints intelligent systems, digital twins, and the IoT as potential tools for creating personalized experiences and facilitating user interactions within the digital environment. Finally, the fourth cluster highlights the convergence of immersive experiences, retail, and customer engagement. The network emphasizes the metaverse's capacity to revolutionize the retail industry by offering unique, personalized experiences to customers. In addition to the findings from the keyword co-occurrence analysis, the application of topic modeling uncovered the metaverse's promising potential in tourism and hospitality. This discovery further underscores the versatility and far-reaching implications of the metaverse across various sectors.

The theoretical implications of this study extend beyond the mere identification of trends and prolific contributors within the metaverse research domain. By revealing several distinct thematic clusters through keyword co-occurrence and topic modeling, the study accentuates the multidisciplinary and far-reaching impacts of the metaverse across various sectors. The unveiled clusters not only emphasize the potential for transformative applications but also underscore the necessity to scrutinize ethical, mental health, and sustainability concerns within this rapidly evolving field. Furthermore, the identification of research collaboration patterns, or a lack thereof, suggests that fostering interdisciplinary and cross-institutional cooperation may be crucial for expediting knowledge dissemination and advancement in the metaverse domain. This study's findings serve as a foundation for future investigations and theoretical developments, ultimately promoting a more comprehensive and nuanced understanding of the metaverse's potential to reshape society and technological systems at large.

From a practical perspective, this study's findings hold great significance for different stakeholders involved in developing and implementing metaverse technologies. This research identified distinct thematic clusters that offer valuable insights for industries looking to utilize the potential of the metaverse to revolutionize various sectors, such as education, governance, healthcare, retail, tourism, and hospitality. These insights could guide strategic decision making and help direct resources and investments toward areas with the highest potential impact. In addition, fostering interdisciplinary and cross-institutional partnerships was highlighted as important by the identification of collaboration patterns. By creating a collaborative ecosystem, the sharing of knowledge, resources, and expertise can be expedited, leading to innovation and ensuring the sustainable growth of the metaverse field. Finally, there is a need for practitioners, policymakers, and researchers to prioritize the responsible and equitable development of the metaverse, of which this review's focus on ethical, mental health, and sustainability considerations serves as a critical reminder. By proactively addressing these concerns, stakeholders can mitigate potential negative consequences, paving the way for a metaverse that benefits society at large and preserves users' wellbeing. This awareness will foster the creation of frameworks and guidelines that ensure the metaverse's growth aligns with ethical standards and promotes a sustainable, inclusive digital environment for all.

Despite the insightful findings, this study has a few limitations. Firstly, the exclusive reliance on Scopus as the source of data may lead to selection bias, as it does not encompass all published literature in the metaverse domain. Expanding the data sources to include other databases could provide a more comprehensive view of the field. This especially pertains to literature that targets practitioners, white papers, reports, and other non-academic publications as well as clusters of research that focus on specific aspects of the field, such as journals investigating the use of visualization and graphics in the metaverse, to give just one example. Additionally, future research could explore the design elements of the metaverse, such as the use of gaming or gamification as well as the tools that are used to create applications. Secondly, the selection of 595 articles may not be fully representative of the entire body of metaverse research, and a larger sample might yield more nuanced insights. Finally, while bibliometric analysis and topic modeling have their merits, these methodological approaches may not capture the depth and complexity of this emerging field adequately. In this regard, qualitative studies that incorporate expert opinions will help to enrich our understanding of the metaverse's evolving landscape and the complexity of this research area.

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