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A Bibliometric Analysis of Metaverse: Mapping, Visualizing and Future Research Trends

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***Abstract*— Metaverse merges diverse digital technologies such as Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), Internet of Things (IoT) sensing technology, Three-dimensional (3D), Extended Reality (XR), and modeling. This research aims to present a bibliometric analysis for visualizing and mapping Metaverse research. In particular, 2673 research articles listed in the Scopus database between the years 2000 and 2023 were analyzed. The knowledge visualization and mapping based on VOS viewer and R studio present the current research status and keywords analysis. This research highlights newer insights into Metaverse applications across various business domains. The findings suggest that the metaverse is highly inclusive. The majority of industries and businesses have adopted several metaverse applications. The present state of the Metaverse literature justifies that Metaverse deep learning, Metaverse blockchain, and cyber-human interaction is a rapidly evolving research domain that engages a set of interconnected fields, which include the Internet of Things (IoT), virtual space, mixed reality and digital twin.**

Keywords*— *Bibliometric analysis, Metaverse, visualizing, Virtual Reality (VR), Augmented Reality (AR), Three dimensional (3D), Thematic (Tm)

I. INTRODUCTION

Metaverse technology integrates Virtual Reality (VR), Augmented Reality (AR), Three-dimensional (3D), and users-digital technology interactions within digital space [1-2]. The term Metaverse first appeared in Neal Stephenson's cyberpunk novel Snow Crash, and it was assumed to be the Internet of the future [3-4]. Since then, Google, Facebook, and Microsoft have been developing a plethora of Metaverse technology [5].

The terms VR, AR, XR and DT, which stand for Virtual Reality, Augmented Reality, Extended Reality, and Digital Twin, respectively, are interconnected with the Metaverse but different in terms of their scope and applicability. Augmented Reality covers digital elements in the physical world, which thereby enhances real-world interactive experiences [6]. Virtual Reality generates deeply immersive digital environments, capable of detaching the users from their present physical environment [7]. Extended Reality indicates an umbrella term encircling AR, VR, and MR, offering a range of captivating experiences. On the other hand, Digital Twin portrays a virtual replica of physical systems, which enables real-time synchronization of the data for simulations and monitoring. Metaverse combines these technologies into a durable, reliable and highly interactive digital space that works much more advanced than individual functionalities. Going beyond and broader than AR, VR, XR, or DT, Metaverse showcases a consistent, shared virtual world that combines real and virtual elements while supplementing diverse applications that include social interactions, education, commerce, and entertainment [8]. By integrating these technologies, Metaverse becomes a platform for complex and multiple user environments that are able to replicate or augment reality.

Recently, the term Metaverse technology has been used to clarify new emerging digital space that will be considered as the post-internet epoch [9]. Thus, the advent of Metaverse technology has received widespread attention due to its novelty as a new paradigm, technology, and mainstream research [10]. However, the existing literature is mostly interdisciplinary and conceptual, except for a few empirical studies [11]. Therefore, it is crucial to use visualization and quantitative tools such as bibliometric analysis for mapping the current research state and assuming a robust map to accommodate potential future research gaps. Researchers also used Bibliometric analysis to decrease the bias in the literature review, clarify emerging trends, explore the intellectual framework of the knowledge domain, and manipulate big scientific data and large volumes of published sources [12].

Furthermore, bibliometric analysis is beneficial for mapping the accumulative explicit knowledge and creating added value from large volumes of published scientific sources using both objective and rigorous tools [13]. This research aims to investigate the present and future research trends of the Metaverse technology by using VOS viewer and RStudio software and is based on 2673 documents spanning the years 2000-2023. The researchers analyzed the metadata of the studies obtained from Elsevier Scopus. In particular, this study introduces a bibliometric analysis of 'Metaverse' research in the literature and specifies existing research gaps. A research trends analysis was performed to investigate the development of the 'Metaverse' and its applications in different business settings.

This paper addresses the following questions:

Question 1: What are the most influential and critical features of Metaverse literature and emerging future research directors?

Question 2: What are the challenges and opportunities of 'Metaverse' research?

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II. Literature Review

The advent of smart digital technologies and artificial intelligence has facilitated the development of a digitally coexisting and emerging extended physical (real) and virtual world [14-15]. The term "Metaverse" is derived from the meta and verse, the term meta finds its deep in roots in philosophy connoting transcendence [11, 16], and the word "universe" implies a physical world. “Metaverse” traces its origins to Neal Stephension's 1992 novel "Snow Crash", where people were engaged in virtual world populated by digital avatars or digital characters [4].

Metaverse technology creates immersive engagement where users participate in various activities and share their intellectual assets and knowledge using 3D tools [17]. Thus, Metaverse can be recognized as a digital replication of the real world or a digital mirror of the world where the multi-user realm combines Augmented Reality (AR), Virtual Reality (VR) or Extended Reality (XR) to create multi-sensory interactions between users and their physical and mirror-worlds [18]. The Metaverse technology is enormous in that it has crucial advantages, and has many applications which include marketing [19], blockchain [11], Healthcare, telemedicine, medicine mental health and physical health [3], education [5], gamification [3, 20], advertising [21] and artificial intelligence [22].

In the healthcare sector, the metaverse enables virtual consultations, allowing remote access to medical checkups or mental health therapies with immersive 3D environment experience [3, 23]. In the education sector, highly immersive learning experiences through virtual classrooms can be created using the ‘Metaverse’ helping students interact with real-life simulations and immersive classroom environments [24]. In the blockchain field, Metaverse supports decentralized platforms to enable secure transactions and to utilize non-fungible tokens (NFTs), thereby improving accessibility and trust in digital economies [11, 25].

All major businesses and industries, including manufacturing, services, social networking, smart governments, smart cities, gaming, hospitality, tourism and others, have embraced Metaverse applications [26]. In recent years, the Metaverse has been the most trending technology in digital technology [27]. According to Facebook and Microsoft, Metaverse is a digital space that replicates and covers the digital representation of users and things [28]. The early adopters of this immersive technology were gaming, entertainment, cloud computing and social media business models [17]. As per [22], the Metaverse space depicts an immersive environment where people live, work and interact between the real world and the Metaverse. In addition, the Metaverse offers an excellent platform due to its interactive and pure-mixed reality that allows users to engage in real-time both in the physical and digital world [25].

Metaverse technology has its applications in various domains that include gamification [29], online shopping [30], e-marketing [31], education [22], cryptocurrency [32], web or social media [33], blockchain [34], and brand management [35].

Although it constitutes a parallel or extended virtual world, Metaverse technology creates an immersive experience that makes individuals feel as if they are inhabiting a real-world environment [11]. According to [18], the Metaverse space implies eight components, namely: identity, users, immersion, diversification anywhere, low latency, economic systems, civilization [14] while [28] assume three major features of the Metaverse: blending real (physical) and virtual world; it facilitates social interactions, among virtual users, entities and virtual markets [36]. Consequently, the Metaverse space has revolutionized our experiences and virtualized each activity by fully crafted Virtual Reality or Augmented Reality enhanced by a variety of immersive technologies that shape the future interaction between human behavior and these cutting-edge technologies. The Metaverse is now considered the potential solution that amalgamates all cutting-edge technologies in the world context [37].

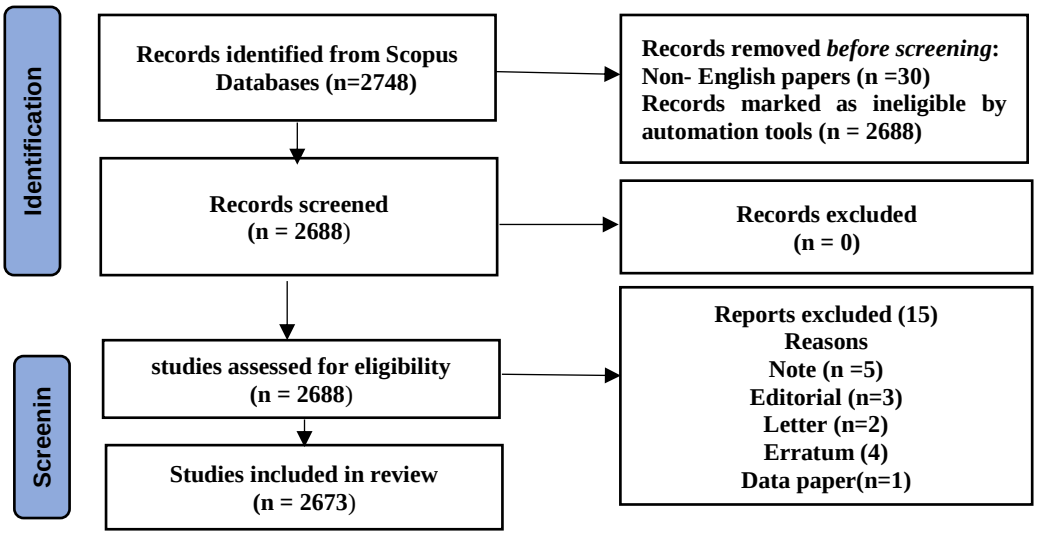

FIGURE I. “PRISMA FRAMEWORK”

III. Research Methodology

VOS viewer provides distance-based visualization of the bibliometric network. It's especially suitable for visualizing large networks [38]. The bibliometric analysis is applied to express the bibliometric structure, which shows interrelations between constituents of the study in the field of Metaverse. The scope of the study is quite detailed to allow for bibliometric analysis. If the papers are in the hundreds (⩽500), then this research field can be assumed to be wholesome enough for conducting bibliometric mapping.

The PRISMA model, developed by [39] supported the methodological framework for conducting a meta-review. Figure (1) below illustrates bibliometric analysis and review development through identification, screening, and inclusion of documents.

A. Data Selection Strategy

This study uses convenience sampling and the Scopus database as the primary source. Researchers chose Scopus because it provides a comprehensive exploration of the social sciences and is popular for conducting diverse studies. Limited access to other databases, such as the SSCI (Social Science Citation Index and Science Citation Index Expanded) within the Web of Science collection, also influenced this choice.

B. Data Collection and Analysis

Data was collected from Elsevier Scopus. Bibliographic data was downloaded for all 2673 publications as illustrated in Table (1). In addition, the publications included in the bibliometric analysis covered the period of 2000 to 2023. The research figured out the applicable keywords and created search methods based on two keywords: Metaverse and Metaverse. Notably, research work increased modestly between the years 2000 and 2023. Retrieving bibliometric data, mapping bibliometric data, and research topic analysis were performed using visualization tools.

A co-word analysis was carried out since it helps to find the conceptual structure of the field under study, its research streams and research topic and to answer other research questions involved in this study [12]. The bibliometric analysis was done with VOS viewer software (version 1.6.17) and RStudio as followed by [40-43].

IV. Results and Discussion

The research on metaverse began in early 2000, which resulted in 2673 documents by 2023 published in Scopus, spanning across 1338 sources which include Journals, Books, etc.

Table I: Publications Profile

Description	Results
Timespan	2000:2023
Sources (Journals, Books, etc.)	1338
Documents	2673
Average years from publication	1.33
Average citations per document	7.988
Average citations per year per doc	2.969
References	105,998

Table 1 presents the annual distribution of Metaverse-related publications from the year 2000 to 2023. The numbers in the graph demonstrate a sharp spike in 2020.

The total number of documents that are Metaverse-related is 2673 from the year 2000 to 2023. The notable spike in publications post-2020 highlights the increasing academic and practical interest in Metaverse studies.

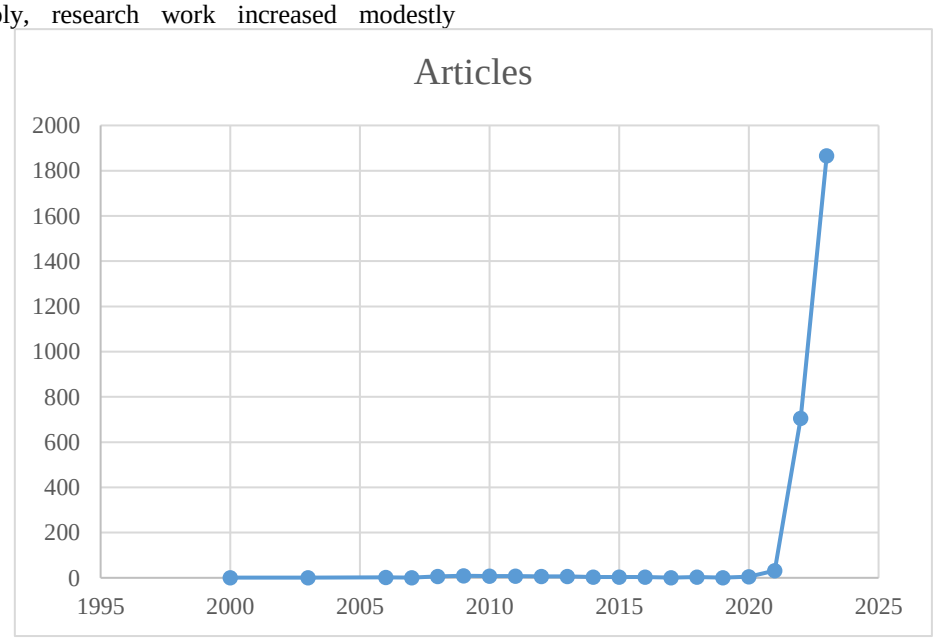

Figure 2. Trends in Metaverse Research Publications from 2000-2023 (extracted from Scopus database)

The rise in research on the Metaverse between 2000 and 2023, as represented in Figure 1, confirms the growing interest in digital technologies and their applications over the years. This rise aligns with an increased adoption of virtual and Augmented Reality, blockchain, and other similar immersive technologies, evidently after 2020 when the upward trend became more prominent. In the 1990s, foundational ideas like Neal Stephenson's 'Snow Crash' introduced the concept of

Metaverse. It emphasizes how industry adoption and technological advancements have modified scholarly interest over the past two decades.

Figure 2 indicates bibliometric data collected from the Elsevier Scopus database. The data includes 2673 documents that were published over the period from 2000 to 2023 and analyzed using VOS viewer and RStudio software.

A. Leading Countries, Institutions, Journals, and Authors

Figure 3 maps the top 10 authors who have published their research on Metaverse and related fields. Leading in this list is Niyato D, who has 52 documents, followed by Wang Y, who has 36 documents, and Li Y, who has 31 documents published. The number of publications gradually decreased after Chen Y secured 10th place with 22 publications. This ranking represents the prominent contributors towards research in the Metaverse, which is leading to the knowledge advancement in this field. This shows potential support in identifying potential collaborators for future research.

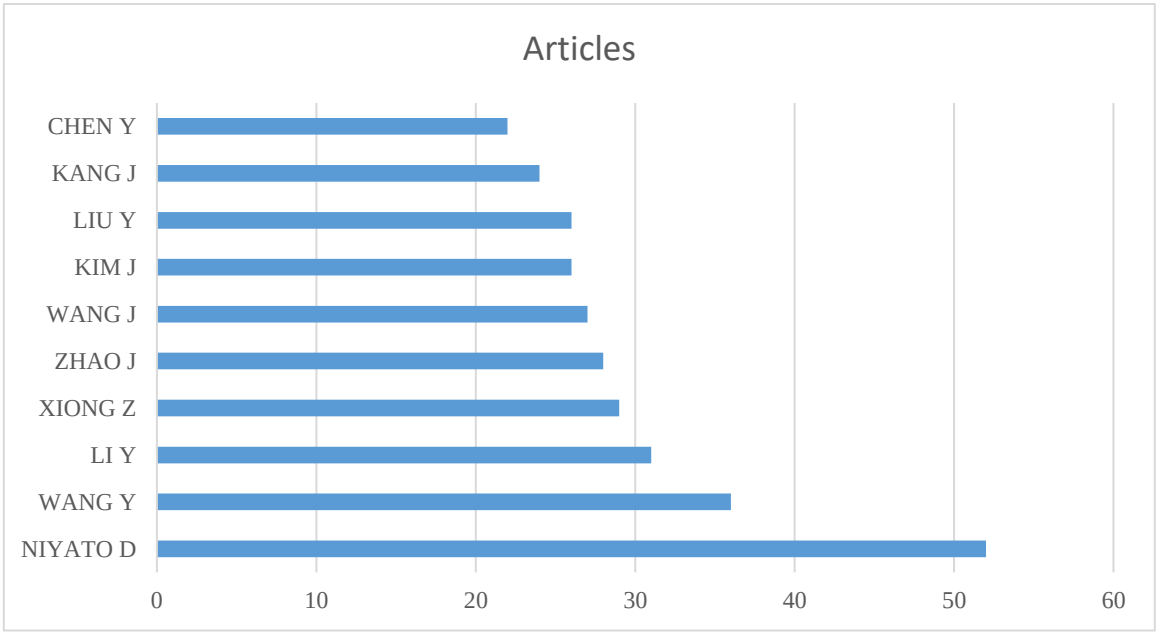

FIGURE 3. TOP 10 AUTHORS WHO HAVE PUBLISHED THEIR RESEARCH ON METAVERSE

Figure 4 highlights the countries of representation for the first authors from the top 20 contributors toward Metaverse research. The leading contributor is China with 2,351 publications, India with 1,026, and the USA with 895. This number steadily declines across the other countries, with France and Portugal contributing 85 and 82 publications, respectively. This country-wise distribution proves the global participation in Metaverse research, with a markable dominance from specific regions. Contributions from countries like China, India, and the USA contemplate their leadership and proactive participation in progressing Metaverse-related research and advancements in technology, especially in AI, digital infrastructure, and Virtual Reality. Thus, shows vital support for studies and practices of new emerging technologies in these countries.

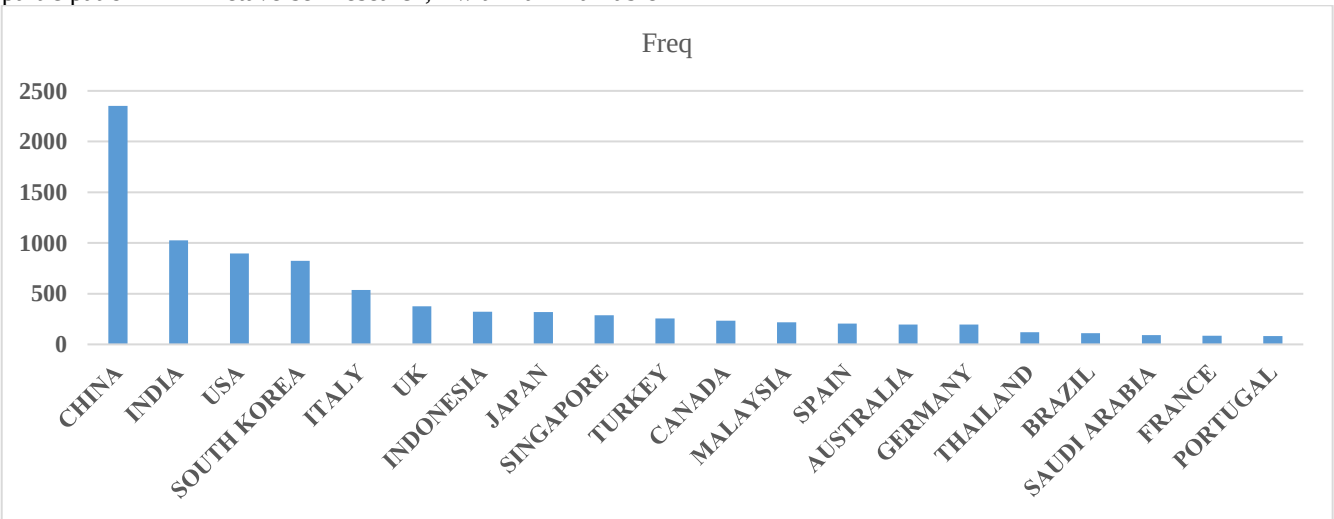

FIGURE 4. REPRESENTED COUNTRIES OF AUTHORS

Table 2 shows an overview of the top 10 most frequently affiliated institutions having 100 or fewer publications on Metaverse-related research. At the top of this list is Nanyang Technological University, with 100 publications, and Shanghai Jiao Tong University, with 48 publications, whereas Fudan is at the 10th position in the list showing 33 publications. It depicts diverse scholarly research engagement among the different institutions in this emerging field. This variation and diversity could be due to differences in focus areas of the research or research funding toward Metaverse-related research.

TABLE 2: AUTHOR-AFFILIATED INSTITUTIONS

Affiliations	**Articles**
Nanyang Technological University	100
Shanghai Jiao Tong University	48
Sun Yat-Sen University	46
The Hong Kong Polytechnic University	43
Sungkyunkwan University	42
Bina Nusantara University	39
Kyung Hee University	35
Tsinghua University	35
Zhongshan Hospital	34
Fudan University	33

Table 3 highlights the top 10 research publication sources for research in Metaverse. At the first position is "*The lecture notes in computer science"* with 77 publications, which includes the "lecture notes in bioinformatics" and "lecture notes in artificial intelligence", which is followed by "*International Conference on Metaverse Computing Networking and Applications Metacom 2023"* with 66 publications. Simultaneously, *the Review of Contemporary Philosophy* ranks 10th with 25 publications. This table depicts increasing academic interest and investment in utilizing and exploring Metaverse technology, its innovation and its advancement.

TABLE 3: TOP 10 RESEARCH PUBLICATION SOURCES

N	**Sources**	**Articles**
1	'Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)'	77
2	'Proceedings - 2023 IEEE International Conference on Metaverse Computing Networking and Applications Metacom 2023'	66
3	'ACM International Conference Proceeding Series'	57
4	'Lecture Notes in Networks and Systems	49
5	Studies in Big Data'	40
6	'IEEE Journal on Selected Areas in Communications'	35
7	IEEE Access	33
8	Journal of Metaverse	32
9	'Linguistic and Philosophical Investigations'	32
10	'Review of Contemporary Philosophy'	25

B. Citation Analysis

Table 4 represents the author impact analysis based on the number of citations. Kim J, published 15 researches, gained 1305 citations; whereas Kim Y-G published 2 documents and received 1304 citations, Park S.M, published 6 papers, received 1300 citations. And so on, Sigala M, has 4 publications, received 1001 citations, ranked tenth. Table 4 highlights the important role of the authors for producing a steady foundation, thereby guiding the progress and development of Metaverse-related research.

TABLE 4: AUTHOR IMPACT BASED ON NUMBER OF CITATIONS

Nu	Author	Documents	Citations
1	KIM J	15	1351
2	KIM Y-G	3	1305
3	PARK S-M	2	1304
4	BUHALIS D	6	1300
5	DWIVEDI YK	14	1151
6	HUGHES L	7	1076
7	RAMAN R	5	1030
8	DUTOT V	4	1028
9	PANDEY N	4	1028
10	SIGALA M	4	1001

Table 4 reveals the top 10 author contributions to Metaverse research in terms of the number of citations.

Moreover, understanding citation patterns elucidates major areas of research that are forming, where blockchain, deep learning, and cyber-human interaction are developing to be prominent fields. These domains have robust co-citation linkages that serve as the backbone of Metaverse-related developments. Nonetheless, there is a conspicuous lack of empirical studies in using these technologies within business and industry contexts. On another note, these studies are dominated by China, the USA, and India, with little input from the newer economies. Redressing this situation will require more collaboration across regions. In addition, broadening the methodological spectrum by including qualitative and experimental research will allow for an in-depth understanding of user experiences and the application of the Metaverse in real-world scenarios.

C. Mapping Networks and Content

Mapping networks and content includes visualizing relationships between entities and content structure, like topics, themes, or ideas [44]. In network mapping, nodes represent entities like individuals, organizations, or concepts, while edges like collaborations or interactions visualize their relationships. In content mapping, the nodes represent information like themes or ideas, and edges illustrate their connections and hierarchy [45]. This section deliberates co-citation analysis, bibliographic coupling, thematic evolution, keyword patterns, and hierarchy clustering for identifying existing research fields and guiding future research.

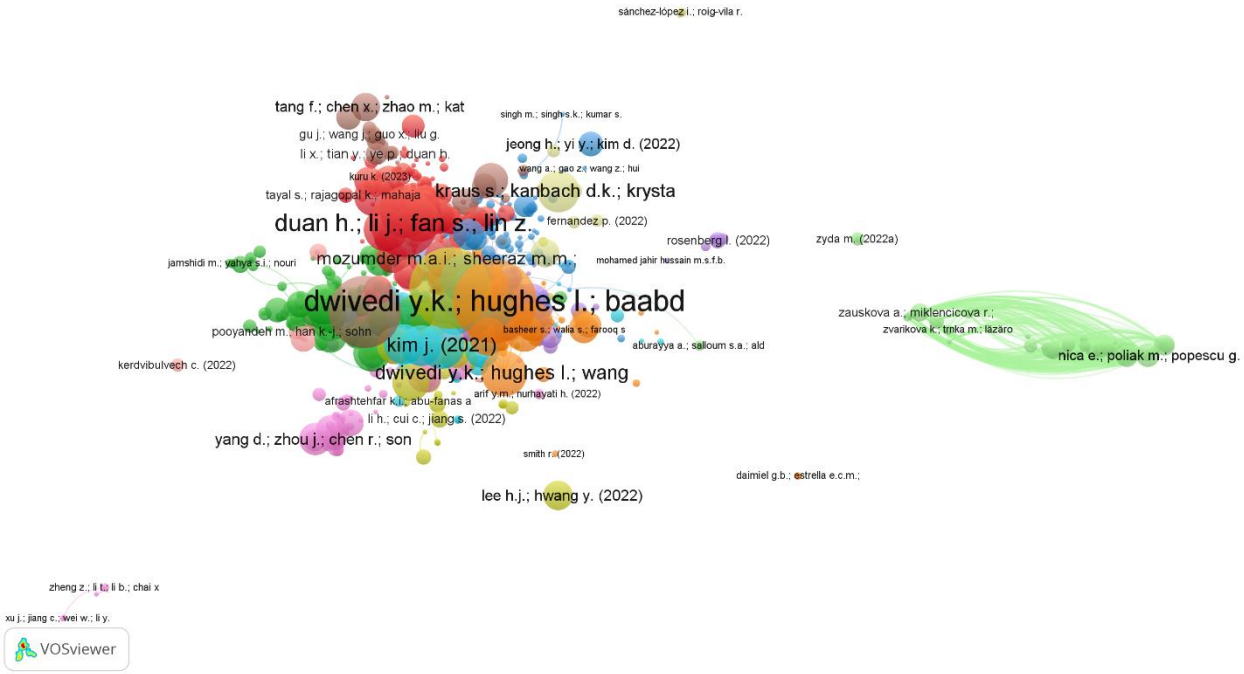

FIGURE 5. BIBLIOGRAPHIC COUPLING OF DOCUMENTS

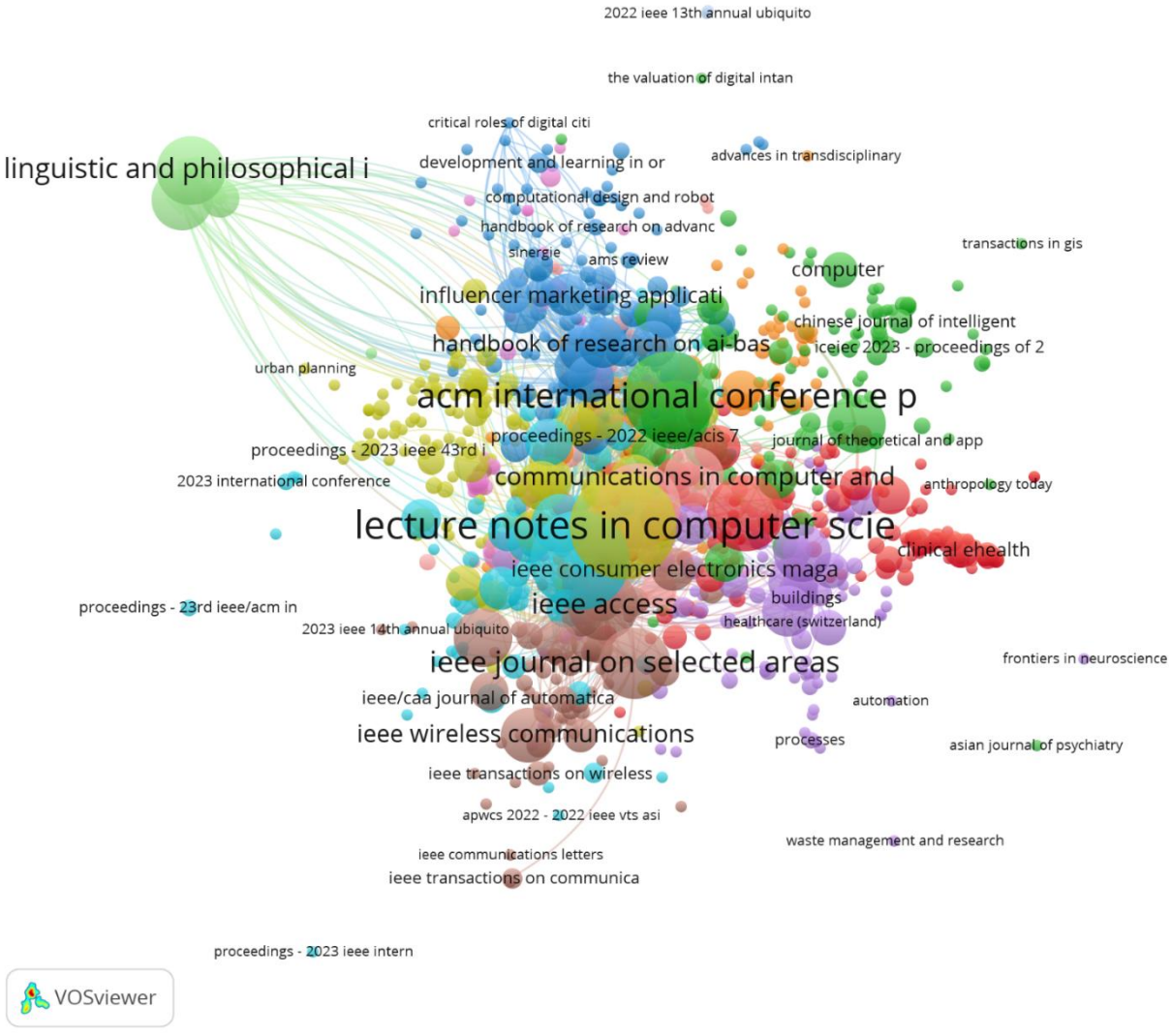

FIGURE 6. BIBLIOGRAPHIC COUPLING OF SOURCES

1) Bibliographic coupling

Figure 5 represents the bibliographic coupling of Metaverse research based on the methodology of [46] Bibliographic coupling categorizes pairs of documents that cite the same third paper to detect research structures and the evolution of interests across time and disciplines. Among the most co-cited works, the paper by [47] stands out as the most influential, followed by the study by [48]. Such analysis pinpoints the most co-cited papers, highlights vital contributions and their connections, and offers researchers a roadmap to understand dominant themes and identify gaps for future exploration.

Figure 6 shows the distribution of sources, where the color of each node reflects the citation relationships within the analysis, with a limit of five citations per document. Based on the model by [40], such an approach highlights the most significant citation networks. 'Lecture Notes in Computer Sciences' series, along with its subseries 'Lecture Notes in Bioinformatics' and 'Lecture Notes in Artificial Intelligence' stand out in the yellow cluster, marking it as a top journal in Metaverse research. Followed by the 'Proceedings of the 2023 IEEE International Conference on Metaverse Computing, Networking, and Applications', placed in the brown cluster, shows sturdy linking with the 'Journal of Communications in Computer and Information Science' in the red cluster, whereas, 'Journal of Studies in Big Data' in the brown-orange cluster. The variation of clusters suggests that this research field attracts the attention of various academic disciplines, which reflects the interdisciplinary nature of Metaverse studies. The connections between these journals show a growing interest in exploring the Metaverse from varied research perspectives.

2) Co-citation

Co-citation analysis involves enabling the characterization of research streams based on the bond of relationships between the documents, recognizing pairs of authors that cite the same source [47]. This study used at least five citations per document and five diverse clusters for the analysis. The green and purple clusters exhibit weaker connections with the red, blue, and light blue clusters. Conversely, the red and blue clusters demonstrate a strong interrelationship, depicted in Figure 7.

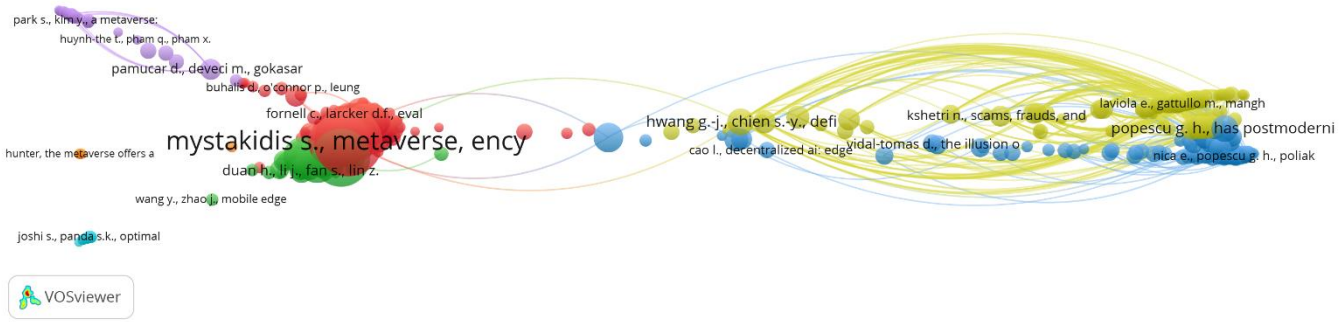

FIGURE 7. CO-CITATION OF REFERENCES

3) Keywords

Keywords can reflect the current trends and research structure of the metaverse. The co-occurrence frequency of keywords is represented by the link strength. The higher the value, the stronger the link. Keyword analysis presents the five occurrences in Figure 8. The analysis of five clusters is identified and reflects our research streams. Metaverse research encapsulates five research fields: Red color represents artificial intelligence, Generative AI, ChatGPT, robotics, medical education, healthcare, telemedicine, personalized medicine, surgical training, and other AI-metaverse applications in medicine. The light green color puts great emphasis on Augmented Reality, mixed reality, virtual community, immersive metaverse technology, innovation, and applications in marketing and education. Blue cluster pertains to the blockchain, 3-D modeling, engineering education, virtual space, arts computing, and higher education. The dark green cluster focuses on deep learning human-centric AI, edge computing, wireless communications, resource allocation and management, games, quality of services and benchmarking. While research in the orange cluster pays attention to the Internet of Things and collaboration. Although the clusters inter-connection can be assessed in the following two ways, the first is cluster overlap and second is the inter-cluster links. The two methods show the relationships and connections between different research themes.

Thematic classification based on the bibliometric mapping identifies some of the mainstream of Metaverse research. The main research streams are presented in Figure 9.

Figure 8 illustrates a two-dimensional matrix, themes are plotted according to their density rank values and centrality. As a result, we can find four kinds of themes:

It is relevant to mention that visualizing thematic clusters has gained awareness in bibliometric analysis. To achieve this end, we employ a thematic evolution map using the software R-studio. The quadrants in Figure 8 are as per the Cobo et al. (2024) classification. The quadrants are as follows:

Lower Right Quadrant (Basic Themes): Themes in the lower-right quadrant are important for research but not yet developed: Metaverse and Blockchain. Although these topics are less developed, they are still in the embryonic stage. According to this group, metaverse and blockchain technologies are considered basic themes to the Metaverse research

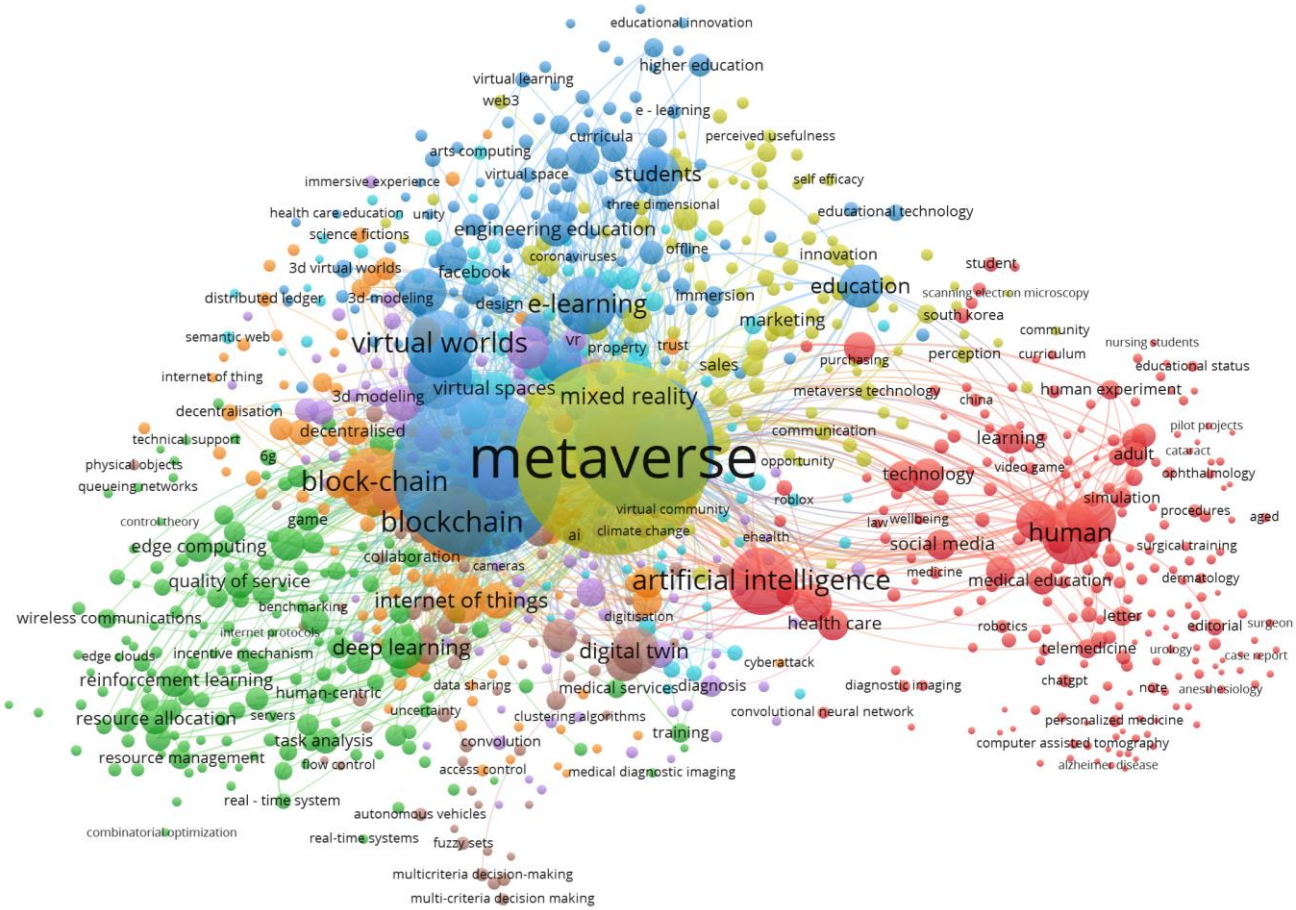

FIGURE 8. CO-OCCURRENCE OF THE KEYWORDS

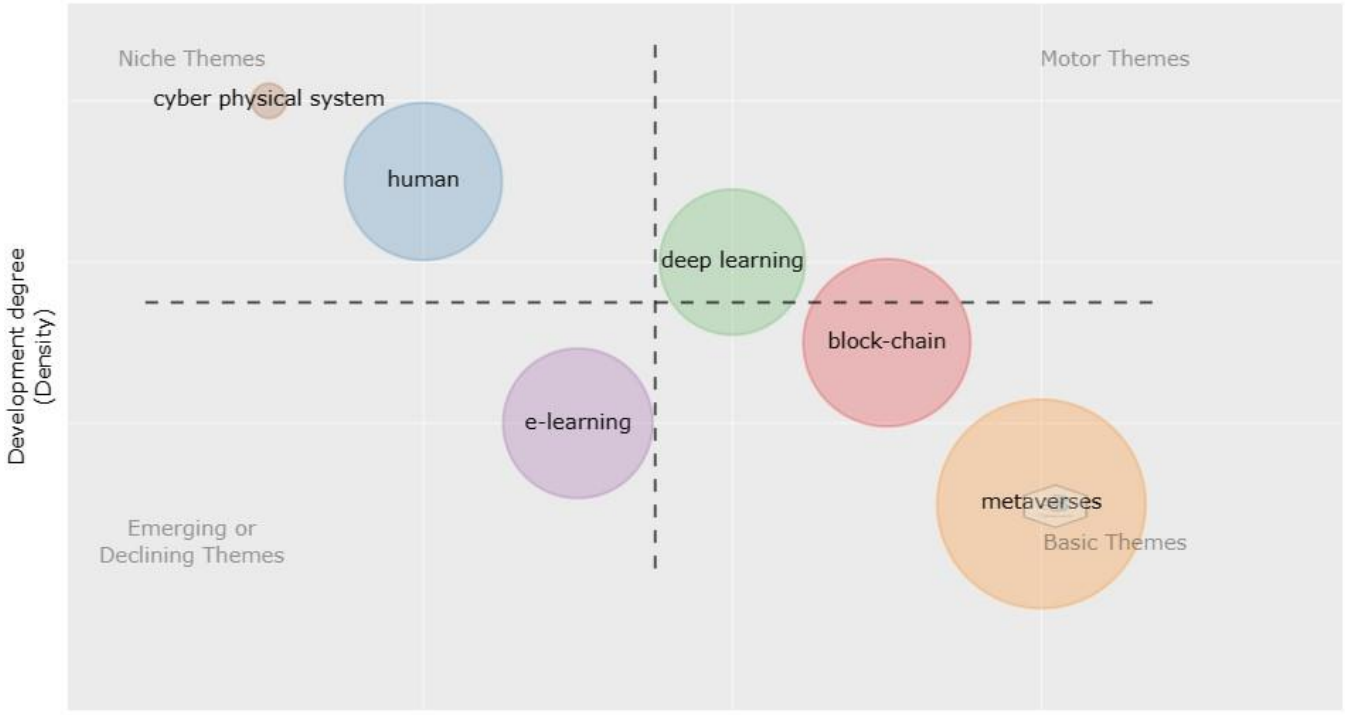

FIGURE 9. THEMATIC EVALUATION

Lower Left Quadrant: Themes in the lower-left quadrant (declining or emerging themes), e-learning, assumes a weak and marginal theme. Namely, e-learning has low centrality and low density, which represents either disappearing or emerging themes in the metaverse domain research.

Upper Right Quadrant: (Motor Themes) Themes in the upper-right quadrant are important and well-developed contributions in the field of the metaverse. Deep learning is an excellent brand of AI and generative AI.

Upper Left Quadrant: (Niche themes) Themes in the upper-left quadrant are cyber-physical systems and have well-developed themes. They reflected highly developed subjects in terms of internal links but unimportant or weak external ties with other fields [49]. Consequently, motor themes, i.e., high centrality and high density and basic themes (low density and high centrality) that represent deep learning blockchain and metaverse reflect red cluster, blue cluster, and dark green cluster in the co-occurrence visualization network. In addition, it can be seen that deep learning and blockchain are relatively accompanied in the middle of the matrix. The most impressive themes and clusters are deep learning, blockchain and metaverse.

V. Future Research Streams

Bibliometric mapping and analysis revealed that the Metaverse has received wide attention in recent years. As an Al-based emerging technology, the Metaverse space offers fully immersive applied paradigms, business models, and innovative products and services. It can provide a creative platform to the needs of entrepreneurs and users. However, based on the current intellectual structure state of the Metaverse literature, the impact of the Metaverse in the realm of business application remains unclear.

There are limited applied and empirical studies of the Metaverse in business and industry, especially in emerging development countries. As Figure (9) shows, the basic themes are Metaverse and Blockchain technology. The catalyst or driver is deep learning, while the niche theme is the interaction between human cyberspace. White e-learning is located in the lower left of the matrix, assumed weak of the Metaverse research. Consequently, their themes identify possible research gaps that must be addressed in the future. Additionally, more applied research is needed in the fields of deep learning, blockchain, FinTech, Metaverse learning, and cyber-human interactions and other emerging fields in the Metaverse economy. The dynamic involvement between users and digital environments can be termed as cyber-human interactions. These cyber-human interactions highlight how immersive technologies, such as the Metaverse, facilitate multi-sensory exchanges and real-time interactions [50-52]. These may integrate virtual avatars, feedback mechanisms, and Augmented Reality to create more seamless transitions between physical and digital realities. It is also possible to describe "Deep Learning and Metaverse" as a method of using advanced neural networks for processing extensive data sets in the Metaverse that give life to intelligent virtual agents, personalized user experiences, and improved decision-making, among others [53-54]. In conclusion, we assume the following Metaverse research stream for the future:

Research stream 1: Metaverse and blockchain

One of the prime benefits of Metaverse in FinTech is its capability to create immersive digital space that supports blockchain technology in various settings, especially its major role in generating augmented simulations with real or extended reality

[55] It has dynamic potential to be an innovative and interactive space for applying blockchain in businesses. Nevertheless, there is still a lack of research in Metaverse blockchain technology even though the Metaverse platforms put to use blockchain and non-fungible tokens [11].

Research Stream 2: Metaverse and deep learning

The artificial intelligence revolution (Al), especially generative Al and deep learning algorithms, is contributing to the enhancement of the Metaverse. The advent of advanced Al tools, techniques and deep learning neural networks facilitates a novel integration between Al and Metaverse [56]. Consequently, future research is necessary to fill these research gaps, especially the generative AI offering novel potential for Metaverse research [57].

Research Stream 3: Cyber-human interactions

Although Metaverse is currently in its early stage, cyber-human interaction has been recognized as one of the important potential research issues. To create a sturdy platform for developing immersive Metaverse space, it is vital to examine the potential impact of the Metaverse technology and elucidate the powerful impact of the current digital technologies on the users. This research attempts to shed light on the pertinent requirements in the Metaverse application and its impact on society [58].

Research Stream 4: Metaverse learning

According to [59], various potential applications of the Metaverse in learning and education are evident. Indeed, Metaverse technology holds the influence and potential to drastically modify the way of E-learning paradigms. The Metaverse technology can offer rich life-like experiences and leverage immersive digital and smart tools in the learning process [60]. Thus, more research is needed that investigates industry 5.0, E-learning paradigms and Metaverse technology [61].

Research in the Metaverse's business considerations, ethics, and AI automation is currently deficient. Integrating blockchain technology with Metaverse economies, particularly in areas of secure, private, and governance-free transactions, needs more work. The application of deep learning technology in enhancing user experiences through AI avatars and behavioral prediction models is still at its infancy. As for cyber-human interaction, the studies should address access, the psychological impacts, and user acclimatization to virtual environments over time. There need to be more psychological, human-computer interaction, and ethics experts in order to design a sustainable, inclusive, and ethical Metaverse environment.

VI. Discussion And Conclusion

The current bibliometric analysis illuminates a burgeoning academic curiosity toward Metaverse technology. The analysis of the Metaverse presented in this research gives invaluable insights into the current research landscape in this innovative field. By analyzing a substantial number of publications from 2000 to 2023 using advanced bibliometric techniques, researchers have been able to map out the key technologies, research streams, and influential contributors within the Metaverse domain. The analysis revealed the interdisciplinary nature of Metaverse technology, encompassing Augmented Reality, Virtual Reality, blockchain, digital twin, internet of things (IoT), and learning systems. This diversity highlights the complexity and interconnectedness of technologies shaping the Metaverse, underscoring the need for collaborative and multidisciplinary research efforts in this area.

In addition, identifying top authors and key publications helps to understand who and what are driving the intellectual trends within Metaverse research, thus providing a sense of direction for knowledge production and critical reflections in the field. The thematic trends of metaverse research depicted four major research themes. Firstly, the basic themes offer foundational knowledge to the field of the Metaverse as an immersive technology and blockchain. Such technologies have generated paths for digital applications in various settings. The current metaverse blockchain applications are split between potential value, new added value and emerging technologies. Blockchain has been identified as one of the fundamental themes and technologies. The blockchain has its distinctive characteristics of transparency, decentralization, and immutability and it is a crucial technology to secure the privacy of users and the Metaverse digital content [59-60]. Thus, the question becomes: How should companies capitalize on the Metaverse technology now and in the near future? How can we prepare our companies to gain strategic advantage? How metaverse technologies shape business models. These questions need rigorous investigation in future research. Moreover, the metaverse blockchain domain reflects emerging value creation of a knowledge-intensive economy. There is a need to examine how blockchain technology leverages new business models in different industries.

The research findings revealed that deep learning is a motor theme that encompasses fields such as AI and Generative AI. It is imperative to examine AI-driven metaverse applications in healthcare, education, marketing, advertising, entertainment, gamification, social media and other dynamic knowledge domains. Further, research should also consider the implications of Generative AI – metaverse interaction. The current research identified two niche themes: cyber-physical systems and humans. These themes represent specialized fields in the metaverse knowledge domain. Building upon topics such as computer-human interaction, cyber-physical technology, privacy, trust, flow state, and digital humanism, the metaverse technology evolves around human-centric AI applications and the ethical and social implications of the responsible metaverse experiences. However, we observed e-learning as an emerging or declining theme (rather declining than emerging). E-learning posits a specific area of transitioning knowledge [61]. Note worthily, the Metaverse paradigm moves to the Generative AI-based immersive technologies, particularly deep learning, blockchain, Augmented Reality, internet of things, internet of everything, edge computing and cognitive computing.

Moreover, the metaverse as a technology relies very heavily on the integration of AI as well as other technologies into one platform, thus enabling people to create fully digital 3D environments that people can use AI for [62]. Since the metaverse consists of virtual worlds outside the physical and real world, AI is fundamental to its functioning as it augments every interaction by using sophisticated algorithms and a variety of collected data [8]. These technologies help the Metaverse provide interactions and simulations of the real world, thus allowing for both virtual and reality to be intertwined effortlessly.

AI algorithms are required to perform complex tasks, which include real-time processing of a 3D environment, enabling personalization, and even simulating intelligent behaviors within avatars and other objects in the digital space [63]. Furthermore, AI also aids in the advanced features that the metaverse possesses, such as natural language processing, machine learning, and a highly complicated and engaging user interaction experience.

In addition, the moral question behind the Metaverse involves fair access, digital inequality, and virtual economies that could be exploited [58]. Properly accounting for these concerns requires an inclusive and equitable framework. Data privacy is a crucial aspect, considering that immersive technologies are designed to gather huge amounts of user information from their behavior and biometric data, hence demanding comprehensive privacy laws and open data control systems. Lastly, beyond just technical functionality, the examination of user experience should be considered in terms of safety, accessibility and psychological health given the addictive and immersive nature of the Metaverse [64].

The alteration demonstrates the significance of creating holistic frameworks that guide Metaverse research beyond the mere technical boundary. While the relevance of deep learning and blockchain is undeniable, their regulation, ethics, and sociocultural aspects still remain largely unexamined. Investigating the adoption of Generative AI in Metaverse systems needs to be done in the context of trust, security, and information abuse. Moreover, the consequences of adopting the Metaverse on the workforce, digital skills, and broader economy are still not well understood. This research needs to include studies that look at the development of Metaverse technology over a significant period of time to be more useful. These considerations can help researchers and policymakers design a Metaverse that is innovative, responsible, and centered on user experience.

The bibliometric analysis of Metaverse research provides an insightful look into its multifaceted impact across various domains. The findings indicate that Metaverse technology, Virtual Reality (VR), integrating Augmented Reality (AR), and other digital innovations are revolutionizing various sectors that include healthcare, education, and entertainment. This research underscores the transformative potential of

Metaverse in creating experiences that are immersive and that enhance user engagement and learning opportunities. The analysis also highlights the burgeoning interest in the application of blockchain within the Metaverse, suggesting a promising future for secure and interactive digital environments. By mapping out these influences, the study not only elucidates the present state of Metaverse research but also discovers key areas for future exploration, promising significant advancements in both theoretical and practical applications.

VII. Implications And Limitations

From an academic point of view, this research presents a comprehensive bibliometric analysis on studies of the Metaverse that contributes to the body of academic literature as well as the business world and gives new insights into a rapidly changing field. Mapping and visualizing the intellectual structure of metaverse research from an academic perspective to determine major themes, key players, and emerging trends. The systematic search helps one understand just how interdisciplinary metaverse technology is since it cuts across domains such as artificial intelligence, Virtual Reality, and blockchain. These findings would build a strong foundation for future researchers who will hence save them in recognizing some of those gaps that need to be filled through further knowledge creation.

For marketing professionals in the business world, this study offers marketers practical applications where they can take advantage of the Metaverse in their marketing campaigns. It identifies game-changing technologies that could transform the way business works, thus giving practical tips on how companies can exploit this technology in creating innovative goods, services, or customer experiences. In addition, mentioning nascent trends like integration with blockchain as well as deep learning application within Metaverse would assist firms in taking up state-of-the-art solutions, thereby reinforcing competitive standing and promoting strategic development. This double influence demonstrates that the paper is a valuable resource that covers the whole spectrum, starting from academia to practitioners intended for using the potential transformational power of the Metaverse. However, similar to any explorative research design, the current research has a few limitations. First, the Scopus database, as the only prominent source for bibliometric analysis, was utilised. Utilizing Scopus and Web of Science ensures more inclusion and diversity. Second, constraints that are in relation to the selected timeframe and the scope of the keywords search may have an impact on the comprehensiveness of the collected data.

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Conflict Of Interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Data Availability

The data supporting the findings of this study are available upon request from the authors.

Ethical Statement

In this article, the principles of scientific research and publication ethics were followed. This study did not involve human or animal subjects and did not require additional ethics committee approval.

Declaration of AI Usage

No AI tools were used in the creation of this manuscript.

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