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**Research Paper**

# Interdisciplinary Research on the Metaverse: General and Library Perspectives on Bibliometric Insights

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## ABSTRACT

This bibliometric study examines Metaverse research (2014-2023) to unravel its evolution, trends, interdisciplinary dimensions, and library engagement. Utilizing Scopus, 2290 articles, conference papers, chapters, and reviews were retrieved using the keyword "metaverse." R Programming and Biblioshiny facilitated data retrieval, and VoS Viewer aided visualisation. The analysis reveals substantial growth in Metaverse publications, dominated by virtual, augmented, and immersive experiences. Interdisciplinary collaboration is prominent, showcasing the metaverse's intersectionality. Libraries actively engage in this research landscape, emphasising their evolving role. The study provides a comprehensive understanding of Metaverse literature, informing researchers, practitioners, and policymakers about its dynamics and interdisciplinary connections.

***Keywords:*** *Metaverse, Bibliometrics, Interdisciplinary Research, Library Perspectives, Evolution, Trends, Immersive Technology, Augmented Reality, Virtual Reality*

The advent of the metaverse, a virtual space blending aspect of the physical and digital realms, has ushered in a new era of exploration and innovation. With its roots in science fiction and manifesting as a tangible convergence of virtual environments, the metaverse holds significant promise across diverse domains. As this concept gains prominence, it becomes paramount to examine the evolution of research within this dynamic landscape systematically. This paper embarks on a comprehensive journey to unravel the intricacies of the metaverse, employing bibliometric insights from both general and library perspectives. Bibliometrics, a quantitative analysis of scholarly publications, offers a powerful lens to discern patterns, trends, and the impact of research in the metaverse domain. By extending this analysis to include library perspectives, we aim to illuminate the academic landscape and the practical implications for information professionals in the metaverse.

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The metaverse, a term popularised by science fiction and now gaining traction in various fields, refers to a collective virtual shared space created by the convergence of physical and virtual reality. This space, accessed through the internet, is populated by digital twins of the physical world or completely immersive virtual environments. The concept has evolved from its early roots in science fiction to a tangible and transformative force in contemporary research. The metaverse holds immense significance in current research across multiple disciplines. It represents a paradigm shift in how we interact with digital environments, offering new opportunities for communication, collaboration, and creativity. This concept is not limited to a single domain; rather, it has the potential to revolutionise industries such as gaming, education, healthcare, and business, among others.

The metaverse is not just a technological innovation but a socio-cultural phenomenon with profound implications. To grasp the full scope of the metaverse, it is crucial to comprehend its evolution, trends, and the interdisciplinary nature of research in this domain. Understanding how diverse disciplines contribute to the metaverse landscape is essential for harnessing its full potential. Furthermore, the engagement of libraries and information professionals in the metaverse is an aspect that requires examination. Libraries play a pivotal role in supporting research and education, and understanding how they navigate the challenges and opportunities presented by the metaverse is crucial for optimising their contributions.

***Significance & Objectives***

This study is significant for several reasons. Firstly, it contributes to the growing knowledge of the metaverse, offering insights into its evolution, trends, and interdisciplinary nature. By assessing library engagement, the study sheds light on the role of information professionals in navigating the metaverse landscape.The implications of this research extend to researchers seeking a deeper understanding of the metaverse, librarians adapting to new challenges, and policymakers shaping the regulatory framework for this emerging space. As the metaverse continues to gain prominence, this study provides a foundation for informed decision-making and strategic planning in various professional domains.

The first objective is to investigate the temporal evolution of Metaverse research from 2014 to 2023, identifying publication trends, patterns, and significant shifts over time. The second objective is to understand the categorization of Metaverse literature to identify key themes, emerging topics, and shifts in focus within the field, providing insights into the development and evolution of the Metaverse concept. The third objective is to investigate the interdisciplinary nature of Metaverse research by identifying collaborative approaches and examining the integration of knowledge across various fields contributing to the Metaverse domain. The fourth objective is developed for the evaluation of the involvement of libraries and information professionals in Metaverse-related research and education, highlighting key contributions and roles played by libraries in shaping the Metaverse landscape. The last objective of the study is to know the utilization of bibliometric indicators to assess the impact of Metaverse-related publications, including the identification of influential authors, journals, and institutions based on paper count, citation counts, and global distribution.

These objectives ensure a comprehensive understanding of the Metaverse literature, its evolution, interdisciplinary nature, and the role of libraries, supported by quantitative bibliometric analysis.

### *Evolution of Metaverse Research*

The metaverse, an immersive, persistent, and interconnected network of virtual worlds, has captured the imagination of researchers and the public alike. While the term gained recent prominence, the research journey leading to this current iteration stretches back decades. This review offers a glimpse into the evolution of metaverse research, highlighting key themes and milestones. a) Early Seeds (1960s-1980s) The roots of metaverse research can be traced to early explorations in virtual reality (VR) and cyberspace. Visionaries like Ivan Sutherland and Michael Benedikt envisioned immersive virtual worlds, laying the groundwork for future technological advancements (Feng et al., 2022; Nevelsteen, 2018; Sin et al., 2023). b) Technological Foundations (1990s-2000s) This era saw significant progress in VR hardware and software development. Games like Second Life and massively multiplayer online role-playing games (MMORPGs) offered early glimpses of social interaction and virtual economies within immersive platforms. The research focused on user experience, avatar design, and virtual community dynamics (Alsaleh, 2022; DeFusco, 2020; Pearce, 2011; Sabzali et al., 2024).

### *Convergence and Expansion (2010s-Present)*

The rise of mobile technologies, augmented reality (AR), and blockchain fuelled a convergence of VR, AR, and other immersive technologies (Jagatheesa perumal et al., 2024; Zawish et al., 2024). Social media platforms began incorporating interactive virtual spaces, and games like Fortnite and Roblox blurred the lines between gaming and social interaction. Research expanded to explore the potential of the metaverse in various domains, including education, work, healthcare, and entertainment (Ahn et al., 2024; Kim & Kim, 2024; Mohammed et al., 2024).

Key themes and milestones in Metaverse research encompass several critical aspects shaping its development. Firstly, interoperability stands as a significant challenge, as researchers strive to establish standards and protocols for seamlessly connecting diverse virtual worlds and platforms, enhancing the overall user experience. Secondly, user agency and identity within the Metaverse are under scrutiny, prompting investigations into ethical considerations surrounding avatar creation, online identity management, privacy, and self-expression, aiming to empower users while safeguarding their rights. Thirdly, the Metaverse presents vast opportunities for creative expression and economic activity, driving research into tools, and platforms for content creation, digital asset ownership, and the establishment of virtual marketplaces. Lastly, ensuring accessibility and inclusion for all users regardless of ability or background is paramount. Thus, research endeavours focus on developing inclusive design principles and accessibility solutions tailored to diverse user needs, aiming to create an equitable virtual environment for everyone (Bobko et al., 2024; Kaddoura & Husseiny, 2023; Lewis et al., 2024; Sykownik et al., 2022).

The metaverse research landscape is constantly evolving, with new technologies and applications emerging. While challenges remain in areas like interoperability, privacy, and accessibility, research plays a critical role in shaping the future of this immersive world. As the metaverse matures, its impact on our society, culture, and individual lives will continue to unfold, demanding ongoing research and thoughtful consideration.

### *Key Themes and Trends in Metaverse Literature in Library*

The emergence of the metaverse, with its immersive and interactive virtual spaces, offers libraries unique prospects and obstacles. As libraries navigate this evolving landscape, research in the field is burgeoning. Several key themes and trends are emerging:

Studies delve into designing and developing virtual library spaces within the metaverse, enabling users to browse virtual shelves, attend author events, and participate in book clubs. Equitable access is a focal point, with research addressing inclusive design principles to ensure accessibility for all users. Furthermore, strategies for curating and preserving digital assets, such as books and multimedia resources, are under investigation (Hedreen et al., 2008; Hopkins, 2023; Tella et al., 2023).

Libraries are exploring the use of virtual environments for interactive learning experiences, including virtual field trips and gamified learning modules. There's also a focus on developing metaverse literacy through educational resources and fostering community engagement by hosting events like book clubs and author talks (Dahya et al., 2021; Hahn, 2018; Hill & Lee, 2009; Lee et al., 2020; Malinchi et al., 2017).

The potential of metaverse platforms for research is being explored, with studies investigating virtual labs, spatial data analysis, and collaborative research projects. Libraries are also leveraging the metaverse to promote open-access principles and collaborate with other institutions on joint research endeavours (Egliston & Carter, 2022; Feng et al., 2022).

***Ethical Considerations and Challenges***

Concerns about privacy, data security, and accessibility within the metaverse are being addressed through research advocating for ethical data practices and strategies to mitigate the digital divide. Additionally, there's an examination of how the metaverse might complement or transform traditional library services, ensuring their continued relevance (Benjamins et al., 2023; Kaddoura & Husseiny, 2023; Smith et al., 2023).

Libraries and information professionals are increasingly involved in the Metaverse, supporting research, education, and community engagement. They provide resources, expertise, and access to digital collections, improving accessibility and learning experiences. Integration efforts include location-based Mobile Augmented Reality (MAR) applications like "PTAR Mobile Augmented Reality (Lib-MAR)," facilitating navigation within library facilities (Oladokun et al., 2023).

Studies demonstrate user interest in Virtual Reality (VR) and Augmented Reality (AR) in libraries, with the potential to enhance library services (Adeyemi, 2023). Libraries serve as platforms for content dissemination and collaboration, enriching learning experiences through educational content and interactive modules (Noh, 2023). Librarians collaborate with educators to develop virtual learning experiences and advocate for metadata standards to improve digital resource accessibility (Oladokun et al., 2023). Libraries play a crucial role in supporting access to information, promoting lifelong learning, and fostering collaboration within the Metaverse. The metaverse presents both exciting opportunities and complex challenges for libraries. By actively engaging in research and development, libraries can adapt to thrive in this evolving landscape. Continued research will be crucial to ensure libraries remain accessible, inclusive, and relevant information hubs for all users as the metaverse matures.

***Interdisciplinary Approaches to the Metaverse***

Various sectors utilize the metaverse, including healthcare, education, information science, tourism, sports, hospitality management, business administration, IT, advertising, and cultural heritage institutions (Curtis & Brolan, 2023). In healthcare, the metaverse facilitates virtual consultations, medical examinations, data visualization, mental health services, and

surgeries (Chen et al., 2022; Tan et al., 2022; Ali et al., 2023). Education researchers contribute expertise in pedagogy, curriculum development, and ethical considerations, shaping immersive learning environments (Classe et al., 2023; Inceoglu & Ciloglugil, 2022; Dwivedi et al., 2022). Sports researchers enhance athlete performance and fan engagement through virtual stadium training and sports marketing (Zhu, 2023; Chohan & Schmidt-Devlin, 2023). IT researchers drive metaverse development in virtual world creation, networking, AI, security, and user experience (Ly, 2023; Radanliev et al., 2023). Metaverse application extends to multidisciplinary fields like cultural studies, telecommunications, and environmental sciences (Aung et al., 2023). Cultural heritage institutions advance metaverse research in virtual museums, libraries, and archives (Kahambing, 2023; Ando, 2013).

***Bibliometric Analysis in Metaverse Research***

Bibliometric analysis, a quantitative method widely used in scientific research, has emerged as a valuable tool for assessing the impact and dynamics of scholarly publications within the metaverse domain. By analyzing bibliographic data such as citation counts, authorship patterns, and journal distributions, bibliometrics enables researchers to gain insights into the structure, trends, and impact of scientific literature.

For instance, studies conducted by Johri et al. (2024), Marcuta (2023), and Tas and Bolat (2022) have leveraged bibliometric techniques to examine the growth and impact of metaverse research (Johri et al., 2024; Marcuta, 2023; Tas & Bolat, 2022). A bibliometric study analyzed Metaverse research publications from 2007 to 2022, collecting data from Web of Science and Scopus databases, totaling 788 and 1,385 publications, respectively. Utilizing VOS viewer software, various analyses were conducted, including co-authorship, publication, keyword, journal, country, and citation analyses. Common terms in the publications included “virtual environments,” “augmented reality,” “virtual reality,” “immersive virtual reality,” “VR,” and “metaverse,” indicating prevalent themes in the research literature (Marcuta, 2023).

The researchers sought to construct a bibliometric map detailing Metaverse usage in education. They examined various factors such as authors, publications, keywords, journals, countries, and citations. Employing a qualitative and systemic research approach, most data was gathered from databases like Web of Science, Scopus, PubMed, and Google Scholar. They focused on terms like “augmented reality,” “virtual reality,” “second life,” and "virtual worlds" (Tas & Bolat, 2022). The research investigates metaverse-related publications through bibliometric methods. It gathers primary data from WOS and Scopus databases spanning 2006-2023, identifying 203 publications. The analysis is conducted using the R program’s Biblioshiny tool, examining co-authorship, publication, keywords, journals, countries, and citations. The main aim of this research is to organize the expanding literature in this field and emphasize future research directions. Sixty-six sample studies were selected through the PRISMA approach and subjected to analysis using both bibliometric methods and systematic literature review techniques (Johri et al., 2024).

This paper intends to do a comprehensive bibliometric analysis of metaverse studies. It gathers key scientific articles, journals, notable writers, organisations, and countries in the field. Term co-occurrence analysis can also help identify relevant research clusters and sub-themes. The purpose is to offer a comprehensive assessment of the metaverse's current state and potential by reviewing past and existing research trends and speculating on prospects. The study gathered 928 journal articles from the Web of Science database and used bibliometric techniques such as co-citation and co-word analysis to identify key publications

and present an overview of the knowledge hierarchy. The paper concludes with insights into the future development of Metaverse research (Abbate, 2022; Wider, 2023).

Bibliometric analysis serves as a powerful methodology for comprehensively evaluating the scholarly landscape of the metaverse, providing valuable insights into its evolution, impact, and future directions. As the field continues to expand and diversify, bibliometric approaches will remain indispensable for tracking and understanding the dynamics of metaverse research.

## METHODOLOGICAL PERSPECTIVES

The present study does a bibliometric analysis of research on the metaverse from 2014 to 2023 using a thorough methodology. The methodology encompasses data collection, inclusion criteria, bibliometric analysis, and visualization techniques to explore the evolution, trends, interdisciplinary perspectives, and library engagement in the field of Metaverse research. The term "metaverse" was entered into the title box of a search that was conducted on January 31, 2024, using the Scopus database as the primary source. English-language articles, conference papers, chapters, and reviews were included in the search, which was conducted between 2014 and 2023. 2290 articles that were found through the search made up the dataset for the study.

### *Inclusion Criteria*

Articles included in the analysis were required to be published in English, classified as articles, conference papers, chapters, or reviews, and fall within the specified timeframe (2014 to 2023). These criteria ensured the relevance, recency, and comprehensiveness of the retrieved data. "TITLE (metaverse) AND PUBYEAR > 2013 AND PUBYEAR < 2024 AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE, "ch") OR LIMIT-TO ( DOCTYPE , "re") ) AND (LIMIT-TO ( LANGUAGE, "English" ) )".

### *Bibliometric Analysis*

The study conducted a temporal evolution analysis to identify publication trends over the selected timeframe, including patterns, milestones, and significant shifts in Metaverse-related publications. Thematic analysis was performed to categorize articles, identify key themes and trends within Metaverse literature, and explore the development of the Metaverse concept over time. Interdisciplinary analysis focused on investigating the diversity of disciplines contributing to Metaverse research, identifying collaborative approaches, and examining the integration of knowledge across different fields. The quantitative analysis utilized bibliometric indicators to assess the impact of Metaverse-related publications, identifying influential authors, journals, and institutions based on paper count, citation counts, and global distribution.

### *Data Visualization*

The retrieval process was conducted using R Programming, utilizing the Biblioshiny tool for its interactive and user-friendly interface. VoS Viewer software was employed for visualization, facilitating the exploration of interdisciplinary connections within the dataset.

## RESULTS

***Table No. 1 Key Metrics and Trends in Metaverse Research (2014-2023)***

| **Description** | **Results** |
|---|---|
| MAIN INFORMATION ABOUT DATA | |
| Timespan | 2014-2023 |
| Sources (Journals, Books, etc) | 966 |
| Documents | 2290 |
| Annual Growth Rate % | 110.87 |
| Document Average Age | 1.33 |
| Average citations per doc | 7.461 |
| References | 79618 |
| *Document Contents* | |
| Keywords Plus (ID) | 7661 |
| Author's Keywords (DE) | 4971 |
| *Authors* | |
| Authors | 5448 |
| Authors of single-authored docs | 362 |
| *Authors Collaboration* | |
| Single-authored docs | 405 |
| Co-Authors per Doc | 3.57 |
| International co-authorships % | 28.34 |
| *Document Types* | |
| Article | 1049 |
| Book chapter | 277 |
| Conference paper | 835 |
| Review | 129 |

Table 1 provides key metrics and trends in metaverse research spanning 2014 to 2023. The dataset encompasses 966 sources and 2290 documents, exhibiting an impressive annual growth rate of 110.87%. Documents are notably recent, with an average age of 1.33 years, and receive an average of 7.461 citations each, indicating substantial impact. Authors, numbering 5448, contribute diverse perspectives, and 28.34% of documents involve international collaboration. Notably, 405 documents are single-authored, while the majority involve an average of 3.57 co-authors per document. The dataset includes various document types: 1049 articles, 277 book chapters, 835 conference papers, and 129 reviews, highlighting the multidimensional nature of metaverse research.

***Table No. 2 Annual Scientific Production in Metaverse Research***

| **Year** | **Articles** |
|---|---|
| 2014 | 2 |
| 2015 | 3 |
| 2016 | 3 |
| 2017 | 1 |
| 2018 | 4 |
| 2019 | 1 |
| 2020 | 4 |
| 2021 | 26 |
| 2022 | 597 |
| 2023 | 1649 |
| Total | 2290 |

Table 2 illustrates the yearly scientific production within Metaverse research spanning from 2014 to 2023, accumulating to a total of 2290 articles. The data reveals a gradual increase in publication output over the years. Beginning modestly with 2 articles in 2014, the number slightly rose to 3 in 2015 and remained stable in 2016. However, 2017 experienced a decline with only 1 article. Subsequently, there was a noticeable uptick in 2018, reaching 4 articles. The trend continued with intermittent fluctuations until 2021, where a significant surge to 26 articles occurred. The most remarkable growth transpired in 2022, with 597 articles, followed by an exponential rise to 1649 articles in 2023, reflecting a period of substantial advancement in Metaverse research.

***Table No. 3 Most Globally Cited Documents in Metaverse Research and Their Impact***

| Paper | DOI | Total Citations | TC per Year | Normalized TC |
|---|---|---|---|---|
| PARK S-M, 2022, IEEE ACCESS | 10.1109/ACCESS.2021.3140175 | 541 | 180.33 | 33.57 |
| DWIVEDI YK, 2022, INT J INF MANAGE | 10.1016/j.ijinfomgt.2022.102542 | 527 | 175.67 | 32.7 |
| DUAN H, 2021, MM - PROC ACM INT CONF MULTIMED | 10.1145/3474085.3479238 | 378 | 94.5 | 6.38 |
| KYE B, 2021, J EDU EVAL HEALTH PROF | 10.3352/jeehp.2021.18.32 | 310 | 77.5 | 5.23 |
| WANG Y, 2023, IEEE COMMUN SURV TUTOR | 10.1109/COMST.2022.3202047 | 203 | 101.5 | 64.31 |
| HWANG G-J, 2022, COMPUT EDUC | 10.1016/j.caeai.2022.100082 | 203 | 67.67 | 12.6 |
| TLILI A, 2022, SMART LEARN ENVIRON | 10.1186/s40561-022-00205-x | 162 | 54 | 10.05 |
| DWIVEDI YK, 2023, PSYCHOL MARK | 10.1002/mar.21767 | 160 | 80 | 50.69 |
| YANG Q, 2022, IEEE OPEN J COMPUT SOC | 10.1109/OJCS.2022.3188249 | 153 | 51 | 9.49 |
| KRAUS S, 2022, INT J ENTREP BEHAV RES | 10.1108/IJEBR-12-2021-0984 | 152 | 50.67 | 9.43 |

Table 3 presents the top 10 most cited documents in Metaverse research, including their total citations, citations per year, and normalized total citations. Notable works include “IEEE ACCESS” by Park et al. (2022) with 541 citations, and “INT J INF MANAGE” by Dwivedi et al. (2022) with 527 citations. Impact metrics such as total citations, citations per year, and normalized total citations provide insights into the influence of these papers within the Metaverse research domain, showcasing trends and significant contributions over time.

***Table No. 4 Average Citations Per Year in Metaverse Research***

| Year | Mean T C per Art | N | Mean T C per Year | Citable Years |
|---|---|---|---|---|
| 2014 | 24 | 2 | 2.18 | 11 |
| 2015 | 17.67 | 3 | 1.77 | 10 |
| 2016 | 7.67 | 3 | 0.85 | 9 |
| 2017 | 151 | 1 | 18.88 | 8 |
| 2018 | 72.25 | 4 | 10.32 | 7 |
| 2019 | 12 | 1 | 2 | 6 |
| 2020 | 36.25 | 4 | 7.25 | 5 |

| Year | Mean T C per Art | N | Mean T C per Year | Citable Years |
|---|---|---|---|---|
| 2021 | 59.23 | 26 | 14.81 | 4 |
| 2022 | 16.11 | 597 | 5.37 | 3 |
| 2023 | 3.16 | 1,649 | 1.58 | 2 |

Table 4 summarizes the average citations per year for Metaverse research papers from 2014 to 2023. The Mean T C per Art column represents the average citations per article, while N denotes the number of articles. Mean T C per Year indicates the average citations received per year by the articles, and Citable Years denotes the number of years each article is considered citable. Significant fluctuations are observed, with notable peaks in 2017 and 2021, suggesting varying levels of impact and interest across different years. The data provides insights into the temporal dynamics and citation patterns within the Metaverse research field over the specified period.

***Table No. 5 Core Sources According to Bradford's Law in Metaverse Research***

| Sources | Rank | Freq | Cum Freq | Zone |
|---|---|---|---|---|
| Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) | 1 | 66 | 66 | Zone 1 |
| Proceedings - 2023 International Conference on Metaverse Computing, Networking and Applications (Meta Com 2023) | 2 | 65 | 131 | Zone 1 |
| ACM International Conference Proceeding Series (ICPS) | 3 | 48 | 179 | Zone 1 |
| Lecture Notes in Networks and Systems | 4 | 41 | 220 | Zone 1 |
| Studies in Big Data | 5 | 40 | 260 | Zone 1 |
| Journal of Metaverse | 6 | 32 | 292 | Zone 1 |
| Linguistic and Philosophical Investigations | 7 | 32 | 324 | Zone 1 |
| IEEE Journal on Selected Areas in Communications | 8 | 31 | 355 | Zone 1 |
| IEEE Access | 9 | 27 | 382 | Zone 1 |
| Review of Contemporary Philosophy | 10 | 25 | 407 | Zone 1 |

Table 5 presents the core sources in Metaverse research based on Bradford's Law. The sources are ranked according to their frequency (Freq) of occurrence in research articles. Cumulative frequency, or cum Freq, indicates how many times an event has occurred up to a specific source, whereas "Zone" categorises sources based on Bradford's Law. The top five key sources are Lecture Notes in Computer Science, ACM International Conference Proceeding Series, Meta Com 2023 Proceedings, Lecture Notes in Networks and Systems, and Big Data Studies. These sites are critical references in the field of Metaverse research and demonstrate a focus of research effort.

***Table No. 6 Local Impact Metrics of Key Sources in Metaverse Research***

| Element | h_index | g_ index | m index | TC | NP | P Y_start |
|---|---|---|---|---|---|---|
| Linguistic and Philosophical Investigations | 12 | 17 | 4 | 308 | 32 | 2022 |
| Sustainability (Switzerland) | 12 | 20 | 4 | 401 | 21 | 2022 |
| IEEE Access | 11 | 27 | 2.75 | 995 | 27 | 2021 |
| Journal of Metaverse | 10 | 21 | 2.5 | 474 | 32 | 2021 |
| Applied Sciences (Switzerland) | 8 | 17 | 2 | 337 | 17 | 2021 |
| IEEE Transactions on Systems, Man, and Cybernetics | 7 | 10 | 3.5 | 151 | 10 | 2023 |

| Element | h_index | g_ index | m index | TC | NP | P Y_start |
|---|---|---|---|---|---|---|
| Procedia Computer Science | 7 | 11 | 0.636 | 250 | 11 | 2014 |
| Review of Contemporary Philosophy | 7 | 11 | 2.333 | 136 | 25 | 2022 |
| International Conference Proceedings Series | 6 | 11 | 0.857 | 133 | 48 | 2018 |
| Electronics (Switzerland) | 6 | 14 | 2 | 202 | 16 | 2022 |

The local effect metrics for notable sources in metaverse research are displayed in Table 6. The h-index, g-index, and m-index are among the metrics used to assess the impact and productivity of publications. "NP" indicates the number of publications, whereas "TC" indicates the total number of citations. The start year of the publication is indicated by "PY_start." Notable sources with extensive publishing portfolios and high citation counts are Sustainability (Switzerland), IEEE Access, and Linguistic and Philosophical Investigations. The table highlights how various sources have influenced scholarly discourse and discussion surrounding the metaverse study topic.

***Table No. 7 Authors' Research Productivity Over Time in Metaverse Studies***

| Author | year | freq | TC | T C p Y |
|---|---|---|---|---|
| Kang J | 2022 | 6 | 255 | 85 |
| Kang J | 2023 | 13 | 144 | 72 |
| Kim J | 2022 | 8 | 619 | 206.333 |
| Kim J | 2023 | 12 | 243 | 121.5 |
| Lee J | 2022 | 9 | 144 | 48 |
| Lee J | 2023 | 9 | 7 | 3.5 |
| Li Y | 2022 | 9 | 165 | 55 |
| Li Y | 2023 | 14 | 40 | 20 |
| Liu Y | 2022 | 6 | 58 | 19.333 |
| Liu Y | 2023 | 13 | 7 | 3.5 |
| Niyato D | 2022 | 8 | 202 | 67.333 |
| Niyato D | 2023 | 36 | 260 | 130 |
| Wang J | 2022 | 7 | 42 | 14 |
| Wang J | 2023 | 16 | 78 | 39 |
| Wang Y | 2022 | 9 | 216 | 72 |
| Wang Y | 2023 | 22 | 453 | 226.5 |
| Xiong Z | 2022 | 7 | 320 | 106.667 |
| Xiong Z | 2023 | 19 | 172 | 86 |
| Zhao J | 2022 | 6 | 186 | 62 |
| Zhao J | 2023 | 17 | 9 | 4.5 |
| Zhao J | 2023 | 15 | 8 | 4 |

Table 7 presents the research productivity of authors in Metaverse studies across different years. The "Author" column lists the authors' names, followed by the "year" indicating the publication year of their works. "Freq" represents the frequency of publications by each author in a particular year. "TC" denotes the total citations received by the author's publications, while "TCpY" shows the average citations per year. The table highlights

variations in productivity and citation impact among authors over time, reflecting trends in their scholarly contributions to the field of Metaverse studies. Notably, authors like Kim J and Wang Y exhibit consistent productivity and high citation rates across multiple years.

***Table No. 8 Author Productivity Distribution According to Lotka's Law in Metaverse Research***

| Documents written | N. of Authors | Proportion of Authors |
|---|---|---|
| 1 | 4340 | 0.797 |
| 2 | 614 | 0.113 |
| 3 | 206 | 0.038 |
| 4 | 91 | 0.017 |
| 5 | 64 | 0.012 |
| 6 | 31 | 0.006 |
| 7 | 23 | 0.004 |
| 8 | 21 | 0.004 |
| 9 | 9 | 0.002 |
| 10 | 13 | 0.002 |

Table 8 illustrates the distribution of author productivity in Metaverse research according to Lotka's Law. The "Documents written" column enumerates the number of documents authored, while "N. of Authors" indicates the count of authors who have contributed to that specific number of documents. "Proportion of Authors" represents the percentage of authors relative to the total number of authors. Lotka's Law, as demonstrated in this distribution, highlights that a small proportion of authors contribute to the majority of documents, while a larger number of authors contribute to fewer documents. This pattern underscores the typical productivity distribution observed in scholarly research within the Metaverse domain.

***Table No. 9 Local Impact Metrics for Influential Authors in Metaverse Research***

| Element | h_index | g_index | m_index | TC | NP | P Y_start |
|---|---|---|---|---|---|---|
| Niyato D | 13 | 21 | 4.333 | 462 | 44 | 2022 |
| Xiong Z | 11 | 22 | 3.667 | 492 | 26 | 2022 |
| Kang J | 9 | 19 | 3 | 399 | 19 | 2022 |
| Miao C | 9 | 13 | 3 | 254 | 13 | 2022 |
| Wang Y | 9 | 25 | 3 | 669 | 31 | 2022 |
| Deveci M | 8 | 12 | 2.667 | 265 | 12 | 2022 |
| Lee J | 7 | 12 | 2.333 | 151 | 18 | 2022 |
| Wang F-Y | 7 | 8 | 2.333 | 268 | 8 | 2022 |
| Zhang X | 7 | 16 | 2.333 | 272 | 17 | 2022 |
| Buhalis D | 6 | 6 | 2 | 1014 | 6 | 2022 |

Table 9 outlines the local impact metrics for influential authors in Metaverse research. The h-index, g-index, m-index, total citations (TC), number of publications (NP), and year of publication start (PY start) are among the factors considered. Niyato D now leads with an h-index of 13 and 462 citations since 2022. Xiong Z has 492 total citations with an h-index of 11. Wang Y, Miao C, and Kang J have also shown good impact metrics, underscoring their

contributions to the field since 2022. These metrics shed light on the productivity and scholarly impact of writers conducting Metaverse research.

***Table No. 10 Top Affiliations by Academic Article Contributions***

| Affiliation | Articles |
|---|---|
| Nanyang Technological University | 75 |
| Bina Nusantara University | 39 |
| The Hong Kong Polytechnic University | 39 |
| Sungkyunkwan University | 32 |
| Inje University | 31 |
| Zhongshan Hospital Fudan University | 31 |
| Sun Yat-Sen University | 29 |
| University of Zilina | 28 |
| Zhejiang University | 26 |
| Jinan University | 24 |

Table 10 highlights the top affiliations based on academic article contributions in Metaverse research. Nanyang Technological University leads with 75 articles, followed by Bina Nusantara University and Hong Kong Polytechnic University with 39 articles each. Sungkyunkwan University and Inje University contribute significantly with 32 and 31 articles, respectively. Notably, Zhongshan Hospital Fudan University and Sun Yat-Sen University are prominent contributors to Metaverse research, each with 31 and 29 articles, respectively. Other notable affiliations include the University of Zilina, Zhejiang University, and Jinan University, reflecting diverse academic involvement.

***Table No. 11 Corresponding Authorship Distribution by Country in Academic Publications***

| Country | Articles | SCP | MCP | Freq | MCP_Ratio |
|---|---|---|---|---|---|
| China | 349 | 254 | 95 | 0.152 | 0.272 |
| Korea | 156 | 129 | 27 | 0.068 | 0.173 |
| USA | 135 | 102 | 33 | 0.059 | 0.244 |
| India | 96 | 76 | 20 | 0.042 | 0.208 |
| United Kingdom | 77 | 45 | 32 | 0.034 | 0.416 |
| Turkey | 68 | 57 | 11 | 0.03 | 0.162 |
| Italy | 67 | 53 | 14 | 0.029 | 0.209 |
| Indonesia | 44 | 34 | 10 | 0.019 | 0.227 |
| Japan | 30 | 24 | 6 | 0.013 | 0.2 |
| Romania | 30 | 10 | 20 | 0.013 | 0.667 |

Table 11 illustrates the distribution of corresponding authorship by country in academic publications related to the Metaverse. China has the highest number of articles (349), with a single correspondent (SCP) rate of 254 and multiple correspondents (MCP) of 95, resulting in an MCP ratio of 15.2%. Korea follows with 156 articles, comprising 129 SCP and 27 MCP, with a 6.8% MCP ratio. The USA contributed 135 articles, with 102 SCP and 33 MCP, reflecting a 5.9% MCP ratio. The United Kingdom, India, Turkey, Italy, Indonesia,

Japan, and Romania also contribute to academic publications with varying ratios of SCP and MCP articles.

***Table No. 12 Most Cited Countries in Metaverse Research and Average Article Citations***

| Country | TC | Average Article Citations |
|---|---|---|
| China | 2880 | 8.3 |
| Korea | 2421 | 15.5 |
| United Kingdom | 1705 | 22.1 |
| USA | 1374 | 10.2 |
| Italy | 422 | 6.3 |
| Turkey | 387 | 5.7 |
| Canada | 337 | 13.5 |
| France | 328 | 25.2 |
| Norway | 316 | 39.5 |
| Australia | 284 | 11.8 |

Table 12 showcases the most cited countries in Metaverse research, along with their average article citations. China leads with 2880 total citations, averaging 8.3 citations per article. Korea follows closely with 2421 citations and an average of 15.5 citations per article. The United Kingdom ranks third with 1705 citations and an average of 22.1 citations per article. The USA, Italy, Turkey, Canada, France, Norway, and Australia also contribute significantly to Metaverse research, each with varying citation counts and average article citations, highlighting their respective impacts on the field.

***Table No. 13 Trending Topics in Metaverse Research over Time***

| Item | freq | year_q1 | year_med | year_q3 |
|---|---|---|---|---|
| metaverses | 1268 | 2022 | 2023 | 2023 |
| virtual reality | 654 | 2022 | 2023 | 2023 |
| augmented reality | 242 | 2022 | 2023 | 2023 |
| marketing | 34 | 2022 | 2022 | 2023 |
| cyberspaces | 20 | 2022 | 2022 | 2023 |
| second life | 16 | 2020 | 2022 | 2023 |
| speech | 6 | 2021 | 2021 | 2022 |
| knowledge based systems | 5 | 2015 | 2020 | 2022 |

Table 13 presents the trending topics in Metaverse research and their evolution over time. “Metaverses” emerge as the most frequent topic, with 1268 occurrences peaking in 2022 and 2023. “Virtual reality” and “augmented reality” follow with 654 and 242 occurrences, respectively, also showing a significant presence in recent years. “Marketing” and “cyberspaces” are among the emerging topics, with 34 and 20 occurrences, respectively, predominantly appearing in 2022 and 2023. “Second life” and “speech” have seen fluctuations, while “knowledge-based systems” had a steady presence from 2015 to 2022, indicating their enduring relevance in Metaverse discourse.

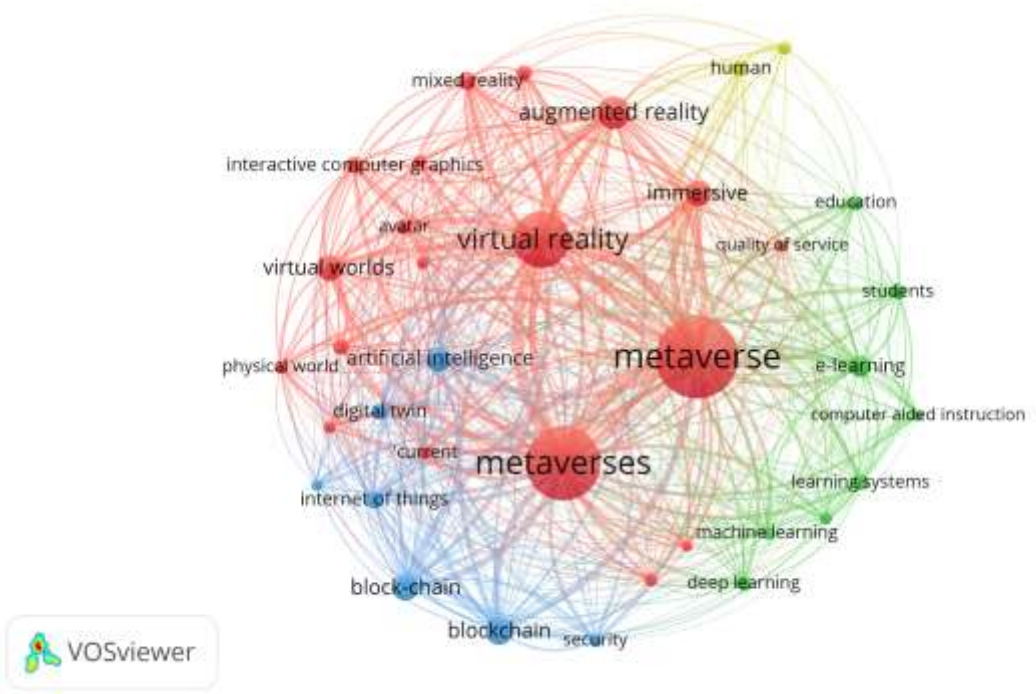


***Figure 1. Most Frequently Used Keywords***

Figure 1 depicts the most frequently used words in metaverse research, as well as their occurrences. "Metaverses" is the most commonly used phrase, with 1268 instances, followed by "virtual reality" (654 occurrences) and "augmented reality" (242); Other noteworthy terms include "block-chain" (212 occurrences), "blockchain" (195 occurrences), and "virtual worlds" (188 occurrences). Terms like "e-learning," "mixed reality," "artificial intelligence," and "interactive computer graphics" are also prominent, demonstrating the broad scope of the metaverse study. These phrases shed information on the field's core subjects and concentrations.

## DISCUSSION

The research question aimed to investigate the temporal evolution of Metaverse research from 2014 to 2023, identifying publication trends, patterns, and significant shifts over time. The analysis reveals a dynamic landscape characterized by profound developments across various domains.

The evolution of metaverse research reflects a transformative journey towards immersive digital experiences and inclusive virtual environments. Initially conceived as a space for social connection and identity exploration, the metaverse has evolved to prioritize security, privacy, and ethical governance. In healthcare, it serves as a platform for safeguarding real-world information digitally and facilitating medical training and remote assistance. Advancements in XR and AI technologies have led to the development of the Human-Intelligent Metaverse (HIM), enabling personalized experiences and immersive interactions. Artificial intelligence plays a crucial role in enhancing various facets of the metaverse, while the integration of 5G technology further elevates the user experience. Blockchain technology ensures security and decentralization, while natural user interfaces shape intuitive experiences.

The Metaverse-as-a-Service model underscores inclusivity in service delivery, benefitting all users, including vulnerable groups. Overall, the evolving concept of the metaverse captures

the imagination of technologists and researchers, promising to transform interactions and engagements in virtual environments. Enabled by emerging technologies, the metaverse continues to advance rapidly, offering a shared world where virtual and reality converge, enriching users' lives globally.

***Key Themes and Trends in Metaverse Literature***

The research question aimed to categorize Metaverse literature to identify key themes, emerging topics, and shifts in focus within the field, providing insights into the development and evolution of the Metaverse concept. The analysis reveals a rich tapestry of literature, highlighting several key themes and trends that shape the discourse surrounding virtual environments. Immersive experiences are central, driving the quest to enhance user immersion through virtual, augmented, and mixed-reality technologies. Social interaction and connectivity emerge as critical aspects, with scholars exploring dynamics within virtual environments.

Ethical and societal considerations underscore discussions on privacy, security, and digital rights, essential for responsible Metaverse development. Additionally, the evolution of the Metaverse concept is evident, transitioning from early visions of interconnected virtual worlds to broader interpretations integrating virtual and physical realities. Interdisciplinary collaboration characterizes Metaverse research, enriching discussions with diverse perspectives from fields such as computer science, psychology, and design, shaping the future trajectory of the Metaverse.

***The Interdisciplinary Nature of Metaverse Research***

The research objective aimed to investigate the interdisciplinary nature of Metaverse research, which is evident through collaborative approaches and knowledge integration across various fields. In healthcare, the Metaverse facilitates remote consultations, medical examinations, and data visualization, enhancing accessibility and equity in healthcare delivery. Education researchers contribute expertise in pedagogy and curriculum development to shape immersive learning environments. Sports sector experts leverage virtual training and fan engagement to elevate athlete performance and increase fan involvement. Information communication technology researchers pioneer Metaverse applications in disaster management and ecosystem forecasting. IT specialists drive research in virtual world creation, AI, security, and blockchain technologies, fostering the development of immersive platforms. Cultural heritage experts utilize specialized knowledge to create virtual museums and libraries, enriching cultural experiences in the Metaverse. By fostering interdisciplinary collaboration and innovative methodologies, researchers from diverse fields collectively contribute to the advancement of Metaverse research, reshaping interactions and engagements in virtual environments. This collaborative effort highlights the transformative potential of the Metaverse across sectors and underscores the importance of interdisciplinary collaboration in driving its development and application. Through shared expertise and diverse perspectives, researchers aim to create inclusive, immersive, and scalable Metaverse platforms that enhance human experiences and interactions in virtual spaces.

***Library Perspectives on the Metaverse***

Libraries and information professionals are increasingly involved in Metaverse-related research and education, recognized for their pivotal contributions to shaping the Metaverse landscape. Through innovative tools like location-based Mobile Augmented Reality (MAR) apps such as "PTAR Mobile Augmented Reality (Lib-MAR)," libraries enhance

accessibility by aiding users in locating facilities within university settings. Study indicates that virtual reality (VR) and augmented reality (AR) technology are highly preferred in libraries, indicating their potential to enhance services and provide better educational opportunities. Institutions like the University of Indiana showcase the effectiveness of AR and VR, attracting significant investments from companies like Facebook. Scholarly exploration emphasizes concepts like meta literacy for both librarians and users, positioning libraries as crucial hubs for Metaverse research. They provide access to scholarly literature, databases, and digital repositories, supporting research and education initiatives. Studies also focus on the potential adoption of Metaverse Academic Libraries (MALs) among students, revealing varying familiarity with VR equipment. At varying levels of popularity, research at US urban libraries examines the applications of metaverse-related technologies such as 3D, RFID, AR, and AI. Libraries are envisioned as platforms for content dissemination and collaboration within the Metaverse, enriching learning experiences through educational content and interactive modules. Collaborations between librarians and educators are vital in developing virtual learning experiences and advocating for metadata standards to improve resource accessibility. Overall, libraries and information professionals play a crucial role in advancing research, education, and knowledge dissemination in the Metaverse.

### *Bibliometric Analysis in Metaverse Research*

Bibliometric analysis serves as a vital tool in evaluating the impact of Metaverse-related publications, enabling the identification of influential authors, journals, and institutions. This systematic approach offers valuable insights into the evolution, impact, and dynamics of Metaverse research, benefiting researchers, practitioners, and policymakers. The application of bibliometric methods to analyze Metaverse literature, assessing citation counts and identifying key contributors and research trends, analyses focusing on specific aspects of Metaverse research, such as its application in education. These studies employed qualitative and systemic research methodologies, collecting primary data from databases like Web of Science and Scopus. The bibliometric analysis summarises important scientific articles, journals, and research clusters. Through co-citation and co-word analysis, identified influential publications and forecasted future research directions.

Bibliometric analysis offers a comprehensive overview of Metaverse research, highlighting emerging trends, popular topics, and areas of interdisciplinary collaboration. It plays a crucial role in understanding the current state and prospects of the Metaverse, shaping the development of this transformative technology across various disciplines and industries.

## CONCLUSION

This study delves deeply into metaverse research from 2014 to 2023, shedding light on its evolution, transdisciplinary characteristics, and library engagement. The temporal evolution analysis revealed a remarkable surge in Metaverse publications, indicating a growing interest and investment in this emerging field. Thematic analysis identified key trends, including the dominance of terms like “metaverses,” “virtual reality,” and “augmented reality,” reflecting the diverse facets of Metaverse exploration.

The interdisciplinary analysis showcased the collaborative nature of Metaverse research, with contributions spanning various disciplines such as computer science, education, and psychology. This interdisciplinary synergy underscores the multifaceted nature of Metaverse exploration and highlights the importance of cross-disciplinary collaboration in advancing knowledge.

Moreover, the assessment of library engagement revealed the active involvement of libraries and information professionals in Metaverse research and education. Libraries play a crucial role in curating and disseminating Metaverse-related resources, supporting researchers, students, and practitioners in navigating this complex domain.

The quantitative analysis provided insights into the impact of Metaverse publications, highlighting influential authors, journals, and institutions. Understanding these quantitative metrics is essential for assessing the scholarly impact and dissemination of Metaverse research.

This study contributes to the scientific understanding of the metaverse by investigating its evolution, multidisciplinary characteristics, and library interactions. The findings provide valuable insights for academics, professionals, and decision-makers interested in researching, comprehending, and influencing the metaverse's expanding field. As the metaverse evolves and grows, more research and collaboration among disciplines and institutions will be required to realise its full potential and solve future difficulties.

Future research in the Metaverse should focus on technological innovation, ethical considerations, and societal impacts. Exploring advanced human-computer interaction methods like natural language processing and brain-computer interfaces can enhance user immersion. Investigating ethical and legal concerns, such as privacy and digital rights, is crucial for responsible development. Examining the Metaverse's potential in education, healthcare, and environmental sustainability offers valuable insights. Cross-platform integration standards, regulatory frameworks, and cultural preservation efforts are essential areas for exploration. Collaborative research initiatives can facilitate interdisciplinary dialogue and foster innovation. By addressing these areas, future research can contribute to the responsible, inclusive, and sustainable development of the Metaverse, ensuring its benefits are accessible and equitable for all.

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***Conflict of Interest***

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