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METAVERSE IN HEALTHCARE: A BIBLIOMETRIC ANALYSIS

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Abstract

The rapid advancements observed during the digitalization era have led to significant growth in healthcare services, resulting in the development of new channels and models aimed at providing treatment at lower costs. One of these models, the metaverse, represents a convergence of technologies such as artificial intelligence, virtual reality, augmented reality, the Internet of Things, and robotic applications, and has emerged as a breakthrough in the digital realm with substantial potential in healthcare. This combination of technologies has allowed healthcare services to become more personalized, breaking down barriers between healthcare providers and individuals. This study offers a comprehensive review of the use of the metaverse in healthcare, presenting a bibliometric analysis of 82 articles indexed in Web of Science (WoS) journals, evaluated through various parameters. The studies are categorized into tables based on year, language, number of highly cited publications, leading countries, universities, and publishers, as well as the most prolific authors and main research areas. Additionally, all the studies were analyzed using the Vosviewer software, a visual mapping technique. This research stands as a significant bibliometric study on the concept of the metaverse in healthcare literature.

Keywords: Metaverse, Virtual Reality, Augmented Reality, Mixed Reality, Healthcare.

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Abstract

The rapid advancements observed during the digitalization era have led to significant growth in healthcare services, resulting in the development of new channels and models aimed at providing treatment at lower costs. One of these models, the metaverse, represents a convergence of technologies such as artificial intelligence, virtual reality, augmented reality, the Internet of Things, and robotic applications, and has emerged as a breakthrough in the digital realm with substantial potential in healthcare. This combination of technologies has allowed healthcare services to become more personalized, breaking down barriers between healthcare providers and individuals. This study offers a comprehensive review of the use of the metaverse in healthcare, presenting a bibliometric analysis of 82 articles indexed in Web of Science (WoS) journals, evaluated through various parameters. The studies are categorized into tables based on year, language, number of highly cited publications, leading countries, universities, and publishers, as well as the most prolific authors and main research areas. Additionally, all the studies were analyzed using the Vosviewer software, a visual mapping technique. This research stands as a significant bibliometric study on the concept of the metaverse in healthcare literature.

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Introduction

The metaverse is an internet-based, three-dimensional (3D) virtual world where people use avatars and holograms to perform daily activities. It is defined as an alternative living space where digital profiles participate in social activities, virtual events, and also engage in an economic life. Thus, the metaverse can be considered another world where the real world is connected and enhanced through virtual reality (1). The number of studies on the metaverse has been rapidly increasing, primarily due to the dizzying pace of changes in information and technology. The term "metaverse" is derived from the words "meta" (beyond) and "universe" (2). This concept refers to spaces where individuals, without physical boundaries, can socialize, explore various places, shop, and carry out daily activities through their digital representations, or "avatars," blending the physical and digital worlds (3,4).

It can be stated that recent studies on the metaverse, a concept with a 30-year history, have gained momentum. The metaverse refers to a universe where virtual and physical worlds merge with artificial intelligence, virtual reality, augmented reality, and other advanced technologies, allowing users to interact and experience in real-time. This online world is a continuously evolving and expanding universe, shaped by user activities and participation. The metaverse is more than just a video game or social media platform. Thanks to advanced virtual reality technologies, experiences within the metaverse can be as enriched as real-world experiences. The most significant reason for the prominence of the metaverse concept has been technological advancements (5). In particular, developments in virtual reality, augmented reality, and blockchain technologies have provided the necessary infrastructure for turning the metaverse into reality. These technologies enable users to have

realistic and immersive experiences within the metaverse and to carry out their daily activities. In this context, Table 1 presents the content of technologies that interact with the metaverse.

Table 1. Technologies Used with the Metaverse

Virtual Reality (VR)	Virtual Reality (VR) is a technology that completely isolates users from the real world and immerses them in a fully immersive digital environment. Virtual reality typically involves a headset worn by the user and motion sensors. This technology allows users to navigate and interact within 3D worlds without engaging with the real world (6). With the concept of the metaverse, virtual reality offers the potential to create environments where users can engage in social, economic, and entertainment interactions outside of the real world (7).
Augmented Reality (AR)	Augmented Reality (AR) is a technology that bridges the gap between the real world and the digital world by integrating digital elements into the real-world environment. AR allows users to interact with digital content without altering their real-world surroundings (8). In the metaverse, augmented reality enables users to interact with virtual objects and characters while navigating the real world, enhancing the interaction between the real and virtual worlds and providing more diverse experiences (9).
Mixed Reality (MR)	Mixed Reality (MR) is a type of technology that allows interaction with both real-world objects and digital objects. MR enables users to naturally interact with digital objects within their real-world environment (10). In the metaverse, mixed reality has the potential to take the interaction between real and virtual worlds even further, creating new experiences and collaborations (11).
Extended Reality (XR)	Extended Reality (XR) is an umbrella term that encompasses all technologies that alter reality. XR includes virtual reality, augmented reality, mixed reality, and other technologies, adding digital/virtual elements to the physical environment at varying levels, thereby blurring the line between the digital and physical worlds (12). In the metaverse, extended reality allows users to transition more seamlessly between real and digital worlds and to experience different types of realities (13).
Holography	Holography is a technology that produces a three-dimensional image of an object with the highest resolution for device-free viewing. Holograms present realistic and detailed images of 3D objects using light (14). In the metaverse, holography enables users to interact more naturally and realistically with virtual objects and characters in real-world environments. This helps make the metaverse experience more immersive and lifelike.
Digital Twins	Digital twins enable the creation of smarter and more responsive systems by facilitating the flow of data between the real and virtual worlds (15). In the metaverse, digital twins allow users to interact with real-world objects in the virtual world, helping them to better understand and manage real-world events. This makes it easier to make more effective decisions and solve real-world problems (16).

Metaverse in Healthcare

Healthcare is one of the most crucial determinants of the mental, physical, and social well-being of all people worldwide. The primary goal of all healthcare systems is to direct activities that promote, improve, sustain, and advance healthcare services (17). Moreover, healthcare can significantly contribute to the efficient development of a country's economy and industrialization. For this reason, the healthcare sector has experienced rapid growth from past to present, and healthcare institutions have strived to adapt to technological advancements to improve themselves. Revolutionary breakthroughs in digital healthcare have been seen as the main drivers of change in the healthcare sector, leading to the widespread use of digital applications in healthcare services. Over time, these developments have significantly impacted the interaction between patients and physicians, and technologies such as blockchain, augmented reality, and virtual reality have brought about substantial changes in treatment methods. Despite the rapid progress in the healthcare sector, challenges such as the unmanageable burden of chronic diseases, rising costs, an aging population, a shortage of healthcare professionals, and limited resources have continued to persist. The post-COVID-19 pandemic period has led to major fundamental changes in the field of healthcare (18). For instance, individuals have become more actively involved in health-related decision-making processes, accelerating the adoption of virtual health systems and digital innovations.

Integrated healthcare systems with metaverse technology provide an interactive and immersive healthcare experience tailored to meet the individual needs of patients (14). The metaverse is composed of advanced technological revolutions that have a significant impact on healthcare, such as artificial intelligence (AI), augmented reality (AR), virtual reality (VR), mixed reality (MR), telemedicine, digital twins, and blockchain (15). The use of these technologies introduces new ways of delivering treatment at significantly lower costs, thereby improving patient outcomes. The application of metaverse technology in healthcare can also enhance patient engagement with the help of high-quality, immersive content and gamification features. This makes it easier for physicians to explain complex concepts and guide patients through procedures (14). Additionally, it ensures that patients use prescribed medications correctly. Digital twin solutions in the metaverse play a crucial role in improving patient awareness about their treatments and increasing their involvement. Data regarding the patient’s vital signs, CT scans, health records, and genetic test results can be integrated into the metaverse to create a digital simulation of the patient's anatomy and physiology. These simulations are used to monitor patients' health and gather important insights. Patients' health data is visualized on a virtual dashboard. At this stage, the technology facilitates communication between physicians, researchers, and other stakeholders, enabling more informed decisions about personalized care and treatment options. Several studies on the application methods of metaverse technology in healthcare are listed below (19, 20, 21):

Bansal et al. (2022) published a survey study that evaluated the current applications of the metaverse in healthcare. According to the survey results, the metaverse has potential benefits in the areas of medical education, diagnostics, and personalized healthcare. However, some challenges associated with its use

were also highlighted. Specifically, issues such as data security and privacy were identified as serious concerns that need to be addressed. The researchers emphasized that the metaverse holds transformative potential for healthcare and suggested that further research is necessary. Thomason (2021) discussed how the digital age and the pandemic have accelerated innovation in healthcare, emphasizing the significance of innovations such as Blockchain and Non-Fungible Tokens (NFTs) in healthcare and exploring the role of the metaverse in uncovering the potential of technology in this field. In his research, Thomason identifies five key areas to explore how the metaverse could influence future changes and transformations in healthcare. These areas include collaborative working, education, clinical care, wellness, and monetization through gaming. The researcher also cautions about the potential risks and challenges associated with the use of metaverse technology. Wang et al. (2022), in their study, developed a metaverse platform called MeTAI, which includes AI-based healthcare applications. This platform offers capabilities such as personalized disease prevention, monitoring, and treatment. According to the results of the study, the metaverse platform was found to be effective in preventing, monitoring, and treating personalized diseases. The researchers emphasized that the metaverse platform has the potential to revolutionize healthcare delivery by providing a more integrated and personalized healthcare experience. Examples of the application of metaverse-related technologies in the healthcare sector are presented in Table 2.

Table 2. Examples of Metaverse Applications in Healthcare (22)

Field	Content	Applications
Surgical Operations	Providing navigation assistance to surgeons during operations, gaining access to the patient's anatomy, and performing surgeries with high precision and minimal complications, virtual guidance and support from a distance.	Proximie (23) Augmedics (24) Vicarious Surgical (25)
Healthcare Education	Providing visual and hands-on learning experience that enhances healthcare professionals' understanding of patient anatomy and how to perform complex surgical procedures.	Osso VR (26) Medivis (27) FVRVS (FundamentalVR) (28, 29)
Treatment	Providing new treatments for patients suffering from chronic diseases, using AR/VR devices to help stabilize and relieve patients with chronic pain, a safer and controlled approach to traumatic events, accelerating cognitive rehabilitation and recovery through AR/VR technology.	AppliedVR (30, 31) Oxford VR (32) XRHealth (33, 34)

Methods

In this study, bibliometric analyses were conducted on the topic of "metaverse in healthcare." The research focused on healthcare-related studies categorized in Web of Science (WoS), with research articles being used as the unit of analysis. Within this scope, 157 studies were identified as published in the WoS database using the specified keywords, and when restricted to articles, 82 studies were found. The information regarding the first 8 questions listed below was obtained from the Web of Science Core Collection page and transferred to a Microsoft Excel file. The data were presented in tables based on the main research questions, including publication year, language, number of highly cited publications, country with the most publications, university and publisher with the most publications, author with the most publications, and list of core research areas with the most publications. The last 3 questions were analyzed using Vosviewer 1.6.19.0 software, a visual mapping tool. Bibliometric analyses included co-authorship analysis, country co-authorship network analysis, and keyword density analysis, all visualized using mapping techniques. The questions addressed in the study are presented below:

1. Which studies have received the most citations related to the concept of the metaverse in healthcare?
2. What is the distribution of publication years for articles related to the concept of the metaverse in healthcare?
3. What is the distribution of publication languages for articles related to the concept of the metaverse in healthcare?
4. Who are the most prolific authors in terms of publications related to the concept of the metaverse in healthcare?
5. What is the distribution of articles related to the concept of the metaverse in healthcare by country?
6. What is the distribution of articles related to the concept of the metaverse in healthcare by universities/institutions?
7. Which publishers have published articles related to the concept of the metaverse in healthcare?
8. What are the main research areas with the most publications related to the concept of the metaverse in healthcare?
9. What is the co-authorship network analysis for articles related to the concept of the metaverse in healthcare?

10. What is the network analysis of co-authorship countries for articles related to the concept of the metaverse in healthcare?

11. What is the keyword density analysis for articles related to the concept of the metaverse in healthcare?

The general framework followed for document search during data analysis is shown in Table 3.

Table 3. Search Framework

Parameters	**Selection**
Selection Approach	Bibliometric Analysis
Database Used	WoS
Tools Used for Analysis	Vosviewer
Search Query	Metaverse, Healthcare
Document Type	Article
Time Range	2021-2023
Subject Area	Healthcare
Total Number of Studies Retrieved	82
Publication Status	Published
Selection Approach	Bibliometric Analysis

Results

In this section of the research, the findings related to studies on the concept of the metaverse in healthcare are presented, focusing on publication year, language, number of highly cited publications, country with the most publications, university and publisher with the most publications, most prolific authors, core research areas with the most publications, co-authorship and country analyses, and the most frequently used keywords.

Table 4. The Most Cited Articles Related to the Metaverse in Healthcare

Article Title	Authors	Year	Journal	Citation
Prediction of user's intention to use metaverse system in medical education: A hybrid SEM-ML learning approach (35)	Almarzouqi, A., Aburayya, A., & Salloum, S. A.	2022	IEEE access	282
Virtual reality consumer experience escapes: preparing for the metaverse (36)	Han, D. I. D., Bergs, Y., & Moorhouse, N.	2022	Virtual Reality	266
Development of metaverse for intelligent healthcare (21)	Wang, G., Badal, A., Jia, X., Maltz, J. S., Mueller, K., Myers, K. J., Niu, C., Vannier, M., Yan, P., Yu, Z. & Zeng, R.	2022	Nature Machine Intelligence	220
Training in lung cancer surgery through the metaverse, including extended reality, in the smart operating room of Seoul National University Bundang Hospital, Korea (37)	Koo, H.	2021	Journal of educational evaluation for health professions	158
Future of mental health in the metaverse (38)	Usmani, S. S., Sharath, M., & Mehendale, M.	2022	General Psychiatry	155
The metaverse: A new challenge for the healthcare system: A scoping review (39)	Petrigna, L., & Musumeci, G.	2022	Journal of functional morphology and kinesiology	154
Metaverse and virtual health care in ophthalmology: opportunities and challenges (40)	Tan, T. F., Li, Y., Lim, J. S., Gunasekeran, D. V., Teo, Z. L., Ng, W. Y., & Ting, D. S.	2022	The Asia-Pacific Journal of Ophthalmology	148
Virtual reality aided therapy towards health 4.0: A two-decade bibliometric analysis (41)	Liu, Z., Ren, L., Xiao, C., Zhang, K., & Demian, P.	2022	International journal of environmental research and public health	115
Virtual reality in Metaverse for future mental health-helping profession: an alternative solution to the mental health challenges of the COVID-19 pandemic (42)	Ifdil, I., Situmorang, D. D. B., Firman, F., Zola, N., Rangka, I. B., & Fadli, R. P.	2023	Journal of Public Health	70
Application of computer-based testing in the Korean Medical Licensing	Huh, S.	2022	Journal of educational	56

Examination, the emergence of the metaverse in medical education, journal metrics and statistics, and appreciation to reviewers and volunteers (43)	evaluation for health professions

Information regarding the top 10 most cited articles related to the metaverse in healthcare is presented in Table 4. According to Table 4, the studies that received the most citations on the metaverse in healthcare were conducted by Almarzouqi et al. (2022), Han et al. (2022), Wang et al. (2022), Koo (2021), and Usmani et al. (2022).

Table 5. Information on the Publication Years of Articles Related to the Metaverse in Healthcare

Year	N	%
2023 (First 6 months)	45	54.88
2022	34	41.46
2021	3	3.66

Information on the publication years of articles related to the metaverse in healthcare is presented in Table 5. According to Table 5, comprehensive studies on the metaverse in healthcare began in 2021, with a significant surge occurring in 2022. By the first six months of 2023, the number of studies had already surpassed those conducted in 2022, indicating that the number of studies may continue to increase in the future.

Table 6. Information on the Languages of Publications Related to the Metaverse in Healthcare

Language	N	%
English	79	96.34
Chinese	1	1.22
German	1	1.22
Korean	1	1.22

Information on the languages of publications related to the metaverse in healthcare is presented in Table 6. According to Table 6, out of 82 studies indexed in the Web of Science (WoS), 79 were found to be published in English.

Table 7. The Most Prolific Authors on the Metaverse in Healthcare

Authors	N	%
Situmorang DDB.	5	6.02
Riva G.	3	3.61
Aburayya A.	2	2.41

Armand TPT.	2	2.41
Athar A.	2	2.41
Cerasa A.	2	2.41
Gaggioli A.	2	2.41
He WG.	2	2.41
Hussain A.	2	2.41
Kim HC.	2	2.41

Information on the most prolific authors related to the metaverse in healthcare is presented in Table 7. The author with the most publications is Dominikus David Biondi Situmorang, with 5 publications. He is followed by Giuseppe Riva, with 3 publications.

Table 8. Countries with the Most Publications Related to the Metaverse in Healthcare

Country	**N**	**%**
USA	15	18.07
China	15	18.07
South Korea	13	15.66
Italy	9	10.84
UK	8	9.63
India	6	7.22
Indonesia	6	7.22
Australia	5	6.02
France	3	3.61
Pakistan	3	3.61

The countries with the most publications related to the metaverse in healthcare are presented in Table 8. The countries with the highest number of publications are the United States and China, each with 15 publications. These are followed by South Korea with 13 publications, Italy with 9 publications, the United Kingdom with 8 publications, India and Indonesia each with 6 publications, Australia with 5 publications, and France and Pakistan each with 3 publications.

Table 9. The University/Institution with the Most Publications Related to the Metaverse in Healthcare

University/Institution	**N**	**%**
Catholic University of The Sacred Heart	4	4.82
Atma Jaya Catholic University of Indonesia	4	4.82
Istituto Auxologico Italiano	3	3.61
Baylor College of Medicine	2	2.41

Dow University of Health Sciences (DUHS)	2	2.41
Harvard Medical School	2	2.41
Harvard University	2	2.41
Institut Mines Telecom	2	2.41
Inje University	2	2.41
Nanjing Medical University	2	2.41

Information on the universities and institutions with the most publications related to the metaverse in healthcare is presented in Table 9. According to Table 9, the "Catholic University of the Sacred Heart" and the "Atma Jaya Catholic University of Indonesia" were identified as the institutions with the highest number of publications.

Table 10. List of Publishers that Have Published Studies Related to the Metaverse in Healthcare

Publishers	**N**	**%**
MDPI	17	20.48
Oxford University Press	10	12.1
Elsevier	8	9.64
Frontiers Media SA	6	7.23
IEEE	6	7.23
Springer Nature	4	4.82
JMIR Publications	2	2.41
Nature Research	2	2.41
PNG Publications	2	2.41
Sage Publications	2	2.41

Information on the list of publishers that have published studies related to the metaverse in healthcare is presented in Table 10. According to Table 10, MDPI was identified as the publisher with the most articles on the concept of the metaverse in healthcare, with 17 publications. Oxford University Press, with 10 publications, and Elsevier, with 8 publications, are the other publishers with the highest number of articles.

Table 11. List of Core Research Areas Related to the Metaverse in Healthcare

Core Research Area	N	%
Human-Computer Interaction	17	20.48
Nursing	7	8.43
Nutrition & Dietetics	6	7.23
Security Systems	6	7.23
Health Literacy & Telemedicine	3	3.61
Psychiatry	2	2.41
Management	2	2.41
Stroke	1	1.21
Palliative Care	1	1.21
Trauma & Emergency Surgery	1	1.21

Information on the list of core research areas related to the metaverse in healthcare is presented in Table 11. According to Table 11, the primary research area for publications related to the metaverse in healthcare is Human-Computer Interaction (HCI), with 17 studies. Human-Computer Interaction is a broad and multidisciplinary research field focused on the design of computer technology and, in particular, the interaction between humans and computers.

Figure 1. Co-authorship Map

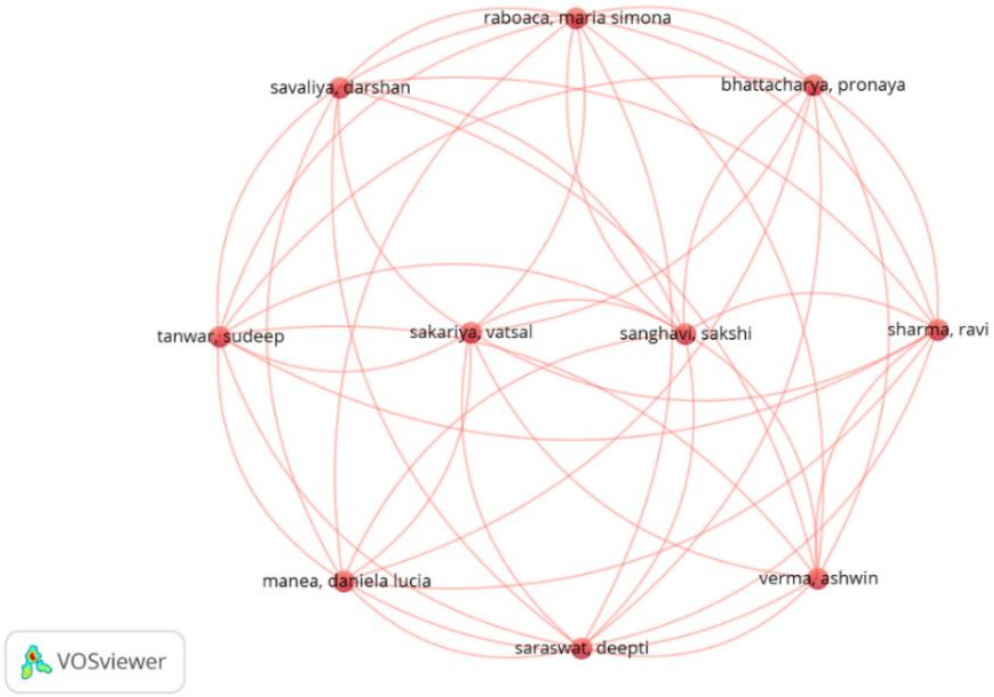
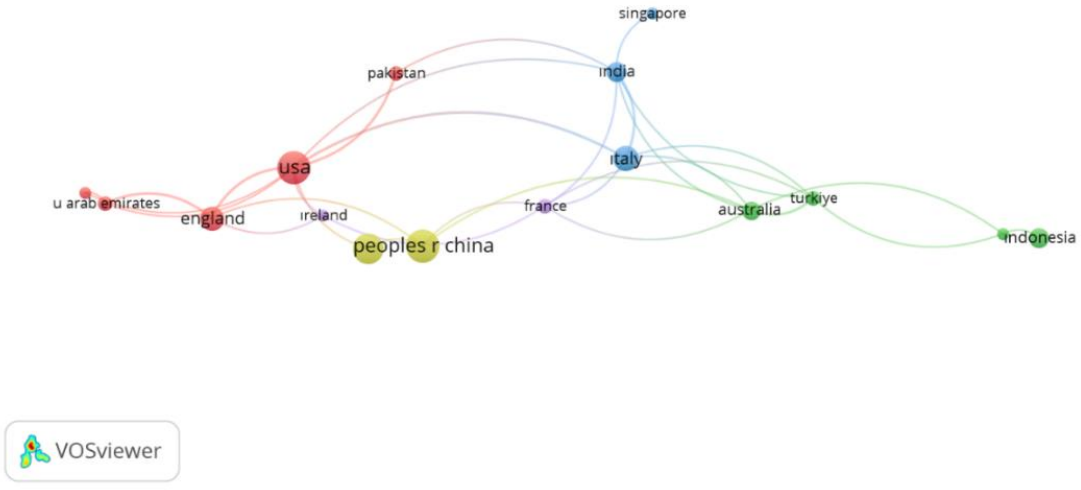


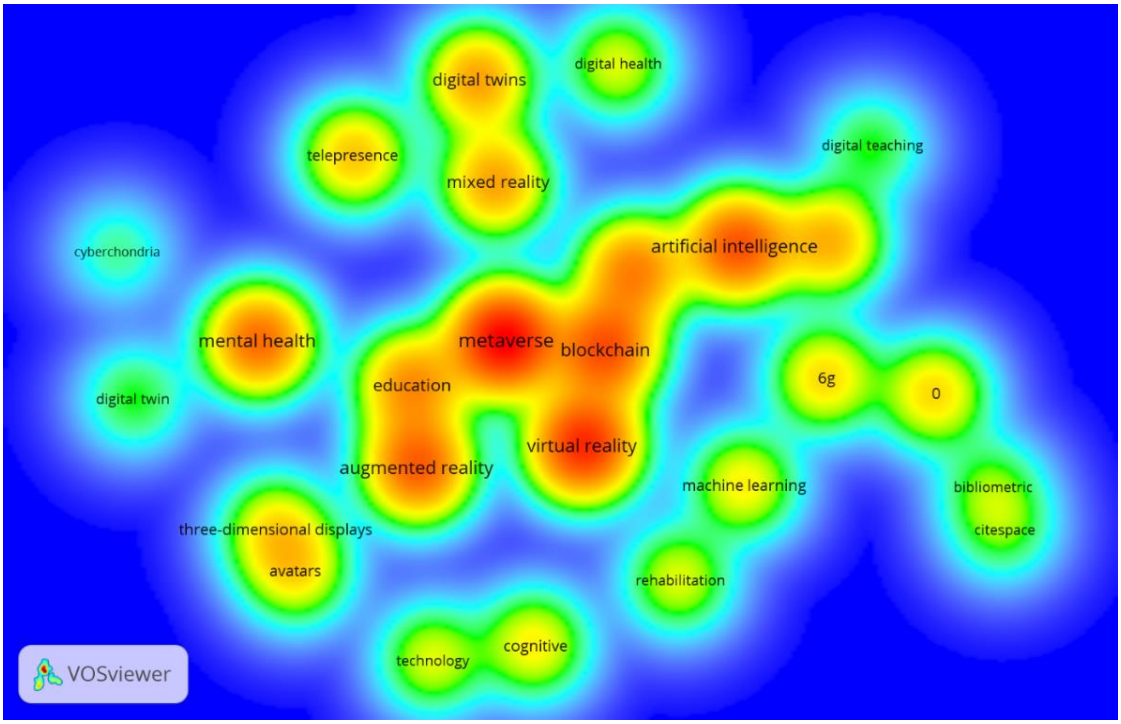
Figure 1 presents the network graph of co-authorship connections. According to Figure 1, it is observed that 10 authors have strong co-authorship connections in the studies.

Figure 2. Network Map of Co-authorship Countries



In Figure 2, the density graph of co-authorship connections by country is shown. According to the co-authorship analysis, the countries with the most co-authorship connections are China, the United States, the United Kingdom, and Italy. Countries such as India, Pakistan, and Turkey have lower research intensity compared to other countries.

Figure 3. Keyword Density Analysis



The most frequently used keywords in articles related to the concept of the metaverse in healthcare are presented in Figure 3. A total of 268 different keywords were used, with the most common keywords being: metaverse (39), virtual reality (22), augmented reality (11), mental health (10), artificial intelligence (9), blockchain (8), healthcare (6), mixed reality (5), education (5), and digital twins (4).

Discussion

Healthcare has always quickly adapted to new technologies and undergone significant innovations from past to present. With advancing technology, healthcare services are offering individuals more effective treatment opportunities. One such opportunity is the "Metaverse," which has recently become a widely discussed and utilized concept in healthcare. Some of its positive impacts include reducing hospital congestion by offering individuals remote treatment options, facilitating the tracking of patients' treatment processes, contributing to public and health literacy, potentially reducing negative situations such as violence in healthcare by decreasing face-to-face consultations, and, most importantly, increasing the interest of healthcare providers and the public in digital technologies. However, there are also some potential risks, such as concerns regarding privacy and security in healthcare. Therefore, the infrastructure of metaverse technology must be robustly established.

Additionally, healthcare services must be provided to patients under conditions that ensure privacy and take security into account.

In this study, academic studies accessible from the Web of Science (WoS) database related to the concept of the metaverse were reviewed, and bibliometric analysis was conducted within the framework of specific questions. The results of the study show that the most cited works on the metaverse in healthcare are Han et al.'s (2022) study titled "Virtual reality consumer experience escapes: preparing for the metaverse" and Almarzouqi, Aburayya, and Salloum's (2022) study titled "Prediction of user's intention to use metaverse system in medical education: A hybrid SEM-ML learning approach." When examining the publication years of studies related to the metaverse in healthcare, it is observed that more studies were conducted in the first six months of 2023 compared to the previous year, indicating that the number of studies will likely increase in the coming years, both in the healthcare field and other areas. The majority of the studies were published in English. In terms of the most prolific authors on the metaverse in healthcare, Dominikus David Biondi Situmorang was identified as the top author with 5 publications. The United States and China were the countries with the most publications, while Catholic University of the Sacred Heart (Italy) and Atma Jaya Catholic University of Indonesia were the institutions with the most publications. The top three publishers of studies on the metaverse in healthcare were MDPI, Oxford University Press, and Elsevier. The core research areas related to the metaverse in healthcare were identified as Human-Computer Interaction (HCI), Nursing, and Nutrition & Dietetics. According to the analyses conducted using the Vosviewer program, Figure 1 shows that the co-authorship map is associated with 10 authors. This analysis reveals that these authors are the most frequently cited interactively in the reference sections of the studies. Figure 2 shows that the countries with the most co-authorship connections are China (15), the United States (15), South Korea (13), the United Kingdom (9), and Italy (8). According to the keyword density analysis, among the 268 different keywords used, the most frequently used were metaverse (39), virtual reality (22), augmented reality (11), mental health (10), artificial intelligence (9), blockchain (8), healthcare (6), mixed reality (5), education (5), and digital twins (4).

This study is expected to contribute to the literature due to its detailed examination of the metaverse concept in healthcare, both in scope and content, and its distinction as a significant bibliometric study on the subject. The limited number of studies on this topic in healthcare across Turkey further emphasizes the importance of the subject. It is believed that more comprehensive studies on the topic in the future will lead to major innovations not only in healthcare but also in all fields.

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