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A bibliometric and systematic review of scientific publications on metaverse research in architecture: web of science (WoS)

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Abstract
The global trends related to the concept of Metaverse in architecture have significantly expanded in recent years, thanks to the increasing number of scientific publications. Systematically examining the literature on this topic and identifying research trends and potential directions provides comprehensive data maps, thus charting a roadmap for researchers interested in working in this field. In this context, the research aims to identify the trends and tendencies of the concept of the Metaverse in the scientific literature over time at the primary analysis levels, such as countries, institutions, resources, articles, authors, and research topics. The research conducted with this aim involves a dynamic, visual, and systematic examination of the academic literature on academic publishing using data accessed without year limitations from the Web of Science Core Collection-Citation database. In the research conducted without year limitations, a sample comprising 334 articles published/planned to be published between 2005 and 2024 is analyzed. The bibliometrix R-Tool was used to enhance the analysis, and metadata was obtained from the WoS database. This analysis analyzed publications, citations, and information sources, including the most published journals, the most used keywords, the most cited and leading articles, the most cited academics, and the most contributing institutions and countries. In conclusion, this study aims to define the profile of international academic publishing in the field of the Metaverse, present its development, identify research fronts, detect emerging trends, and uncover the working themes and trends in the Metaverse specific to architecture. This study describes the profile of international academic publishing on the metaverse, presents its development, identifies research frontiers, identifies emerging trends, and reveals metaverse study themes and trends in architecture. As a result, education, virtual perception of space, building operation and maintenance, building evacuation, BIM (Building Information Modeling), cultural heritage, physical environment, built environment/planning, smart home, design and creativity, universal design/accessibility, sustainability, smart city/GIS, urban transportation systems, and in-use evaluation are identified as themes that have been studied in relation to the metaverse concept in architecture and design disciplines.

Keywords Architecture · Bibliometrix · Metaverse · Biblioshiny · Design · Augmented reality

Extended author information available on the last page of the article

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Introduction

Information and communication technologies are undergoing rapid change and transformation every day. The concept of technology, which developed with computers in the 1990s, evolved into the Web in the 2000s, Web 2.0, the second stage of the evolution of the Web in the 2004s (Murugesan, 2007), telecommunications in the 2010s, and the metaverse in the 2020s (Lee, 2021).

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Until the 1990s, Web 1.0 emerged as the first version. In this process, access to information was only one-way and there was no interaction. The Web 1.0 era was focused on making connections and obtaining information on the internet. Web 2.0, which emerged in 2004, includes forums, comments, blogs and social networks. However, Web 2.0 allowed users to share information as well as read. Thus, people started to communicate, collaborate and interact in another way (Alby, 2007). The concept of Web 3.0, known as the semantic web, which became active in 2010, made it possible to conduct a content search using keywords. Here, instead of humans, computers have come to the forefront to produce new information and think. Web 4.0, which started in 2016, focuses on access and intelligence (Latorre, 2018). Using machine learning technologies and artificial intelligence, users started to interact with data. Interpreted as an iteration of the Internet, the metaverse brings together a large number of different virtual spaces that provide access to various projects and entertainment environments using the full spectrum of augmented reality. In summary, the metaverse is the latest in a long line of emerging technologies (Nath, 2022). All these definitions are presented in the graph in Fig. 1.

The concept of Metaverse (fictional universe), which first emerged in Neal Stephenson's cyberpunk novel "Snow Crash" in 1992 (Ağırman & Barakalı, 2022), has seen a significant increase in studies on this subject after Marc Zuckerberg changed the name of Facebook and announced it as "Meta" in 2021 (see Figure 1). The word Metaverse is a combination of the prefix "meta" (meaning "beyond") and the suffix "verse" (short for "universe") (Dionisio et al., 2013). In this context, the Metaverse is defined as a virtual structure that allows participants to participate in real life or recreate real life through self-created avatars in a virtual metaphorical environment, independent of temporal and spatial constraints (Díaz et al., 2020). The concept of a metaverse or virtual world is a social and economic universe beyond commerce and entertainment, where digital

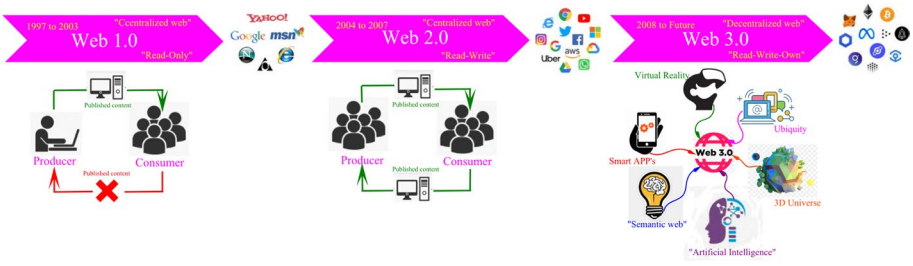

Fig. 1 The Changing Face of the Internet: Journey from Web 1.0 to Web 3.0 (Nath, 2022)

users or avatars represent the individual (Lee, 2021). The Metaverse offers a potential environment in various fields, such as culture, education, design, and entertainment.

In the literature, there are studies on metaverse conducted with various keywords in different databases. For example, Abbate et al, (2022) conducted a study with the keyword "metaverse" in the title, abstract and keywords in the Scopus database, regardless of the time period studied, and the aim of the study was to review the studies on the Metaverse using bibliometric analysis. Feng et al. (2024), (2024) was conducted in the WOS database with the keywords "metaverse" and "Non-Fungible Token" between 2000 and 2023. Tas and Bolat, (2022), unlike these studies, conducted a bibliometric analysis of studies on the use of metaverse in education. Similarly, Bızel (2023) conducted a bibliometric analysis on the concept of "metaverse" and "education" in education between 2004 and 2022. Zhou et al. (2023) analyzed articles on the concept of metaverse in different databases between 1992 and 2022 and examined the concept of metaverse, its technical features, user behaviors and their theoretical foundations. Studies in the literature have examined the concept of metaverse in general or in relation to education. The scope of this study is the relationship between metaverse and architecture.

Given its inherent connection with architecture and design, this study primarily focuses on the Metaverse universe. Therefore, this study conducts a bibliometric examination of research related to the Metaverse and performs content analysis specifically within architecture. Bibliometrics is a quantitative analysis method that uses mathematical and statistical tools to measure the interrelation and impact of publications within a specific research field (Lee et al., 2020). Bibliometric research encompasses empirical methods focusing on quantitative literature studies (Ding et al., 2001). As a powerful tool for analyzing the information domain and revealing the cognitive-epistemological structure of the field (Van Eck & Waltman, 2010), it provides a macroscopic view across numerous academic studies. This method highlights influential research, authors, journals, institutions, and countries within a specific domain (Mora et al., 2019). Based on this premise, this research chose the WoS database for bibliometric analysis. Indeed, in every article indexed in WoS, research data such as authors, sources, cited references, keywords, and more can be accessed (Wang et al., 2022a, 2022b, 2022c). Furthermore, the Metaverse literature obtained from the WoS database is systematically analyzed using the Bibliometrix and Biblioshiny software packages available in the R program. The following scientific questions guide this research.

RQ1: What is the development trend of publications in the Metaverse field over the years?

RQ2: How are the relationships among stakeholders in this field, such as authors, institutions, and countries?

RQ3: What are the main keywords in the study domain, and how are they clustered?

RQ4: What are the key elements, trends, and themes that characterize the global development of the Metaverse literature?

This bibliometric and content analysis conducted within this framework presents structured information and a comprehensive examination of the Metaverse field. Gaps, significant, and emerging points in the area are identified for researchers in this domain. The significance and contribution of this study lie in its examination of the literature related to the Metaverse and architectural design up to the present day.

Methodology

Data collection

This study uses the Web of Science (WoS) database for bibliometric analysis. Indeed, the Web of Science database is preferred due to its wide range of tools for manipulating search results and its general, cited reference, and advanced search features (Norris & Oppenheim, 2007:163; Merigó et al., 2015; Gaviria-Marin, 2019). On April 29, 2024, a comprehensive search was conducted across all fields in the Web of Science database using the following search query: "metaverse" AND "architect*" or "design" or "architectural studio" or "architectural education" or "building" or "architectural space" or "built environment" AND "virtual space" or "mixed reality" or "augmented reality" or "extended reality" or "cyberspace" or "virtual reality" or "virtual environment" or "virtual worlds" or "digital world" as keywords (Fig. 2). This search resulted in the identification of 513 studies.

The flow chart of the study is shown in Fig. 3.

Bibliometric analysis

Bibliometric analysis, a quantitative approach to analyzing academic literature using bibliographies to identify, evaluate, and monitor published research, first used in 1969 (Broadus, 1987; Lee et al., 2020), is employed in this study to analyze trends and potentials in the field of the Metaverse. Bibliometric analysis distills a comprehensive overview of a specific area by processing a large volume of literature. In this context, bibliometric study provides a broad perspective on extensive research literature and enables the quantitative and objective delineation of research topics from the past to the present (Chen et al., 2021). The bibliometric analysis method analyzes development trends in various scientific research fields (Li & Ye, 2016). It aids researchers in creating knowledge maps that represent information structure in a particular area and examine their characteristics using statistical and mathematical methods (Ding et al., 2001; Godin, 2006).

In this study, the graphical web interface Biblioshiny, based on Bibliometrix 3.0 (URL-1), is used within the R software and RStudio environment to create knowledge maps. R software is noted as a dynamically writable and interpretable programming language for statistics and data analysis (Diez-Vial & Montoro-Sanchez, 2017; Donoho, 2021; Khan et al., 2016; Xu & Marinova, 2013).

The Bibliometrix R package plays an essential role in scientific methodology by providing a set of tools for quantitative research. This package is developed within the R

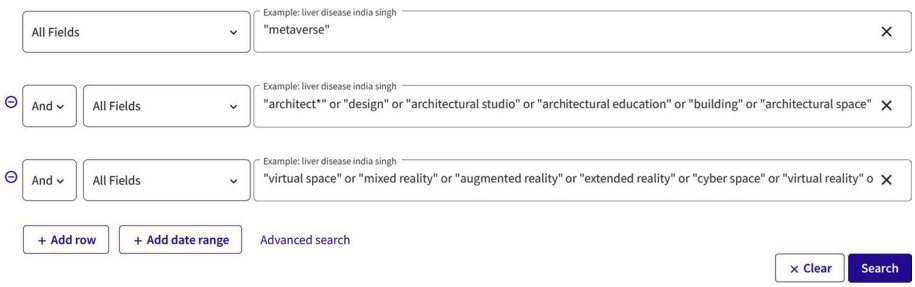

Fig. 2 WoS search screen

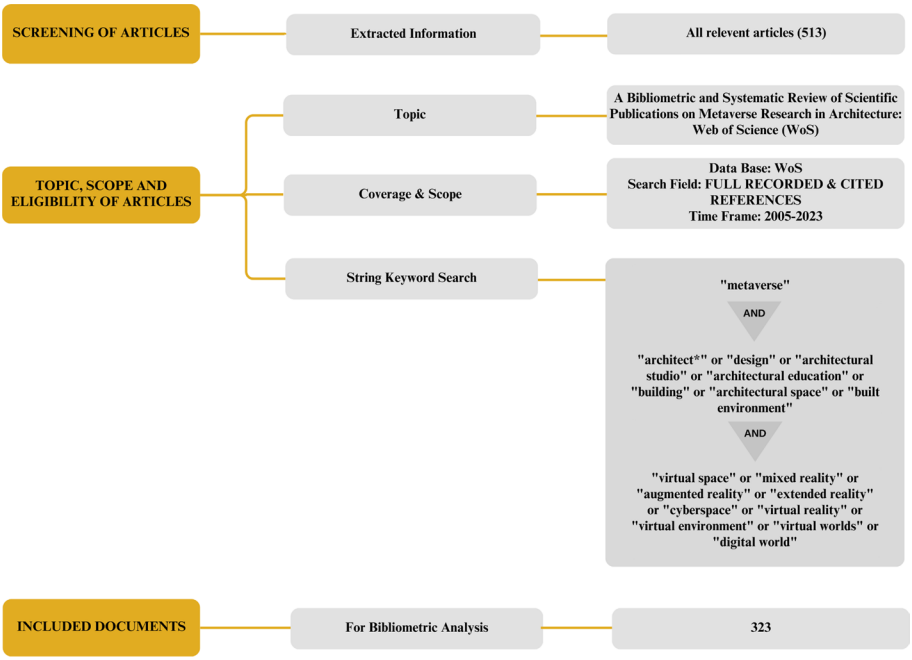

Fig. 3 Flowchart of the study

programming language, an open-source environment and ecosystem. The R language offers substantial opportunities in scientific computation due to its multitude of practical statistical algorithms, access to high-quality numerical data, and integrated data visualization tools (Aria & Cuccurullo, 2017; Xie et al., 2020). Within the scope of this study, the literature data obtained from the WoS database was analyzed using the bibliometric analysis method within the Bibliometrix software environment. The knowledge maps and data obtained are presented in the findings section.

Results

Distribution of annual documents

To reflect the trends in literature research, it is essential to analyze the accelerations that studies have demonstrated over time (Xie et al., 2020). In this context, it was determined that this research, without a time constraint, covers the relevant data from the years 2005 to 2023. It is seen that the number of research studies published on the Metaverse from 2005 to 2023 shows a similar trend with a small number of publications until 2021 but shows a significant increase starting from 2022 (Fig. 4). Based on the graphical data, it is anticipated that research in the Metaverse field will rapidly increase.

According to the analysis data from the Web of Science category, the top five categories prominently featured are Engineering Electrical Electronic (103), Computer

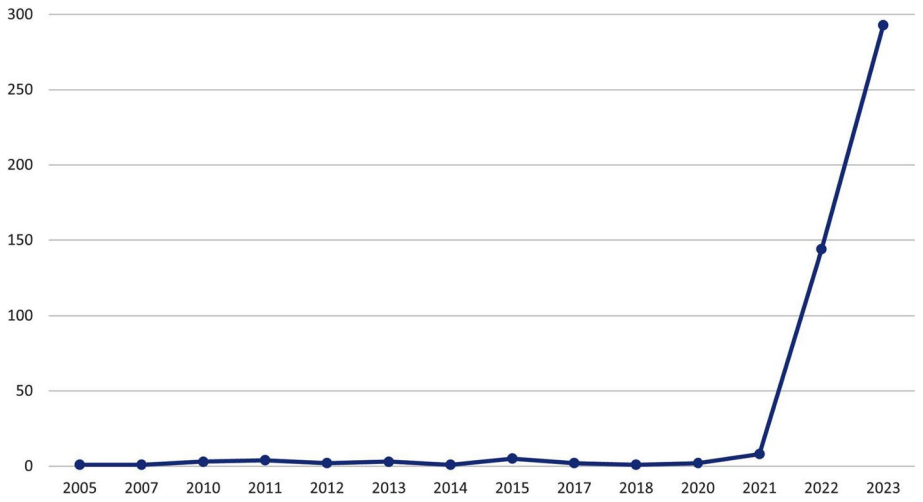

Fig. 4 Number of documentations by year

Science Information Systems (102), Telecommunications (86), Computer Science Artificial Intelligence (58), and Computer Science Interdisciplinary Applications (58) (Fig. 5).

When the classification of the retrieved studies is examined in the context of Sustainable Development Goals, it is determined that 168 studies were conducted for Quality Education, 61 for Good Health and Well-being, 32 for Sustainable Cities and Communities, 30 for Industry Innovation and Infrastructure, 17 for Responsible Consumption and Production, 3 for Affordable and Clean Energy, 1 for Gender Equality, 1 for Decent Work and Economic Growth, 1 for Reduced Inequality and 1 for Life on Land (Fig. 6).

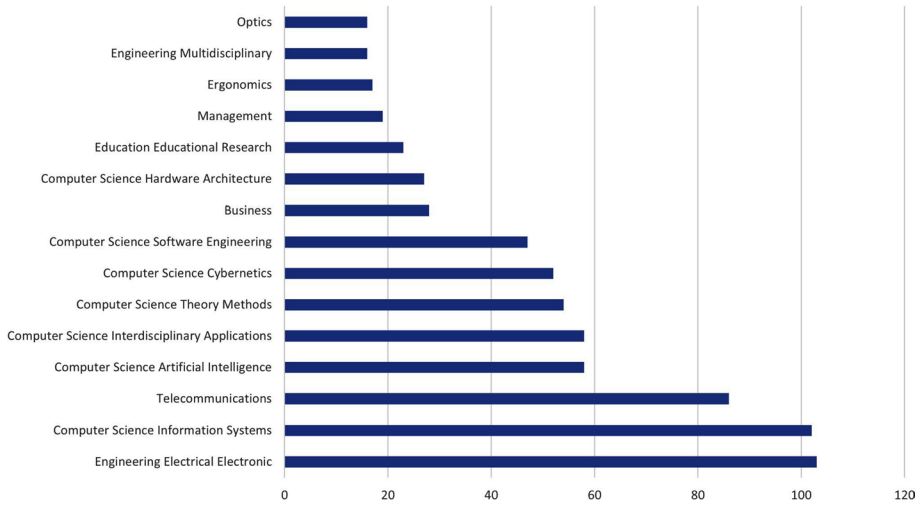

Fig. 5 Number of documentations by WoS Categories

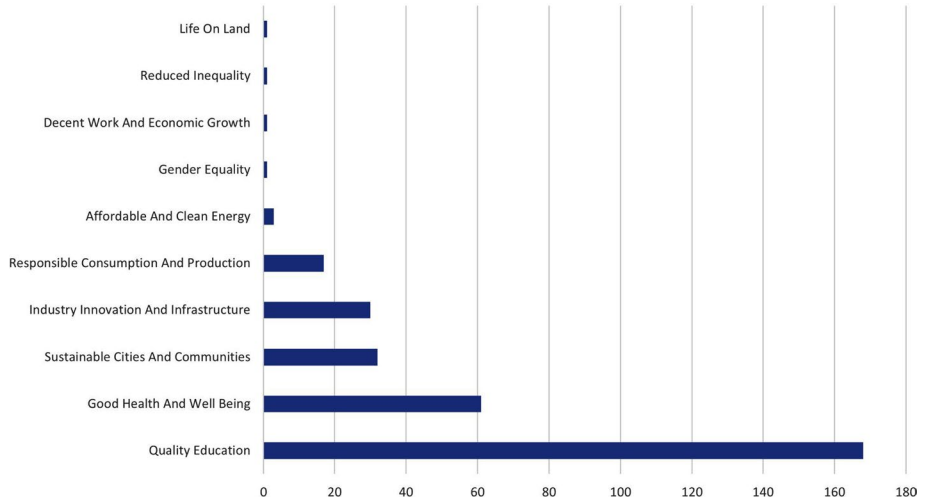

Fig. 6 Number of documentations by Sustainable Development Goals

As a result of the studies on the Metaverse, 291 articles, 128 proceeding papers, 46 review articles, 37 early access, 5 book chapters and 4 editorial material were identified (Fig. 7).

Data screening and inclusion criteria

As a result of the search conducted in the WoS database on April 29, 2024, a total of 513 sources potentially suitable for this study were identified. In this research, 323 documents were retrieved from 199 sources. In this study, which did not apply any

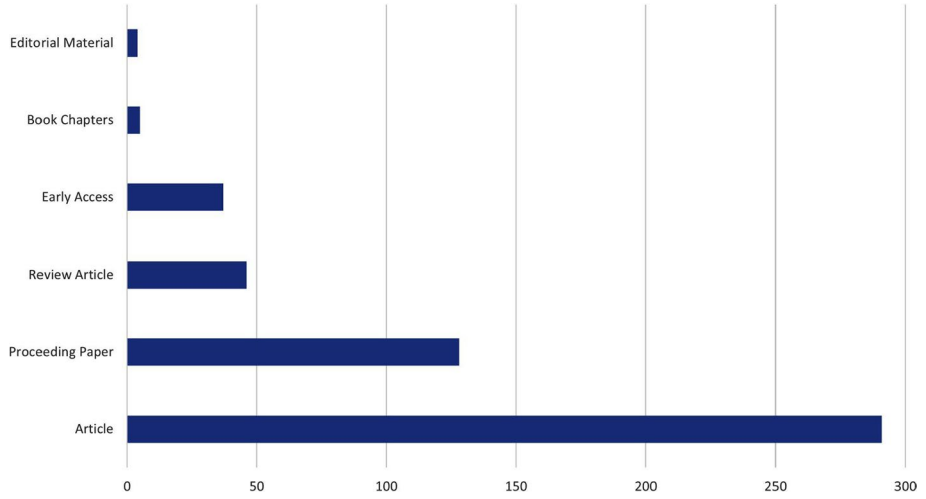

Fig. 7 Number of document types

Fig. 8 Primary data information in Bibliometrix software

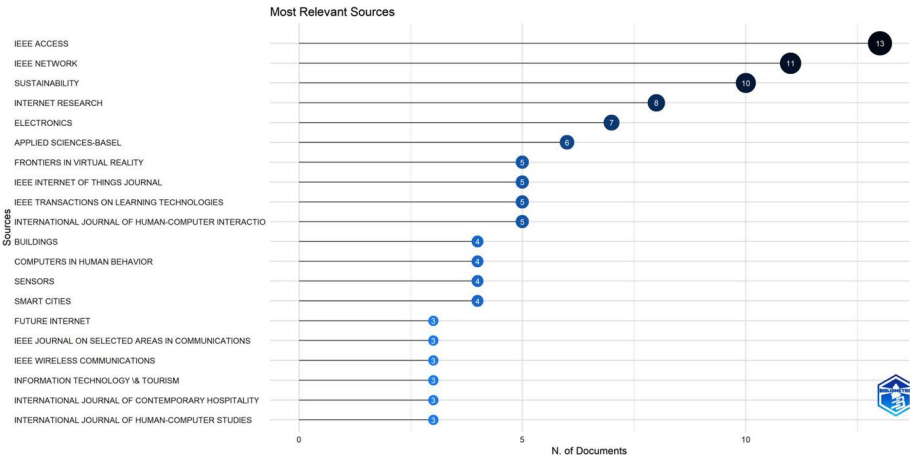

Fig. 9 Top 20 most relevant sources

time constraints, the retrieved documents spanned the period from 2005 to 2023. The data file downloaded in Bibtex format from the WoS database was uploaded to the Bibliometrix software (URL-1). In this step, publications written in English, accessible, and peer-reviewed were preferred for examination. In this context, the document type was limited to 'Article/Article; Book Chapter/Article; Early Access/Article; Review; Early Access/Review.' As a result of these restrictions, a total of 190 studies were excluded from the analysis. Figure 8 provides general information about these data.

Most relevant sources

The retrieved articles have been published in a total of 289 different sources. The sources with the most publications are the 'IEEE Access' (N = 13), 'IEEE Network' (N = 11), 'Sustainability' (N = 10), 'Internet Research' (N = 8) and 'Electronics' (N = 7) publications. Figure 9 presents the top 20 sources with the highest number of publications.

Most frequent words

Keywords ensure the general comprehensibility of a research topic and its content. The analysis of high-frequency keywords reflects important and current topics in the Metaverse field. In this context, Fig. 9, which includes the 'TreeMap', illustrates the tree structure of the 50 most frequently used keywords. In this representation, the size of the rectangle indicates the frequency of usage of the term within the rectangle. In this context, 'virtual-reality (50), augmented reality (30), design (28), system (24), technology (22)' are identified as the top five prominent terms. Additionally, this situation can also be observed through the created 'WordCloud,' which represents the frequency of usage of key terms in a word cloud (Fig. 10).

Most relevant countries

Figure 11 shows the collaborations between co-authors and their countries. In this context, it is understood that the most co-authors are commonly found in China. In terms of the number of articles published by a single country; China (N = 51), USA (N = 27), Korea (N = 26), Italy (N = 12) and the United Kingdom (N = 9) are ranked as the top five. Similarly, for multiple-authored articles, the top five countries are as follows: China (N = 35), United Kingdom (N = 11), India (N = 8), USA (N = 6), Malaysia (N = 6), Singapore (N = 6), Korea (N = 5), Italy (N = 5) and USA (N = 5). When looking at Fig. 11, the turquoise bars represent single-country publications (SCP), while the orange bars represent multi-country publications (MCP).

Most relevant authors

Figure 12 presents a list of the top 20 authors with the highest number of publications. In this context, it is observed that Niyato has the highest number of publications (10). Following Niyato (N = 11), Xiong (7), Wang (6), Bibri (5), Kim (5), Li (5), Liu (5) and Wang (5) respectively.

Authors' production over time

The article dataset related to Metaverse publications includes a total of 1044 authors. Figure 13 displays a diagram depicting the top 20 most productive Metaverse authors during the study period. The size of the dots in this diagram represents the number of articles, while the colors' dimensions represent the annual total citation counts. Regarding the number of articles published during the study period, the top three most productive authors are Niyato (10 articles), followed by Xiong (6 articles), Wang (5 articles), Bibri (2 articles), and Kim (4 articles).

Most relevant affiliations

When evaluating the institutions where publications on the Metaverse have been conducted, Nanyang Technology University (Number of Articles = 20), Singapore University of Technology and Design (N = 15), Norwegian University (N = 12), Sungkyunkwan

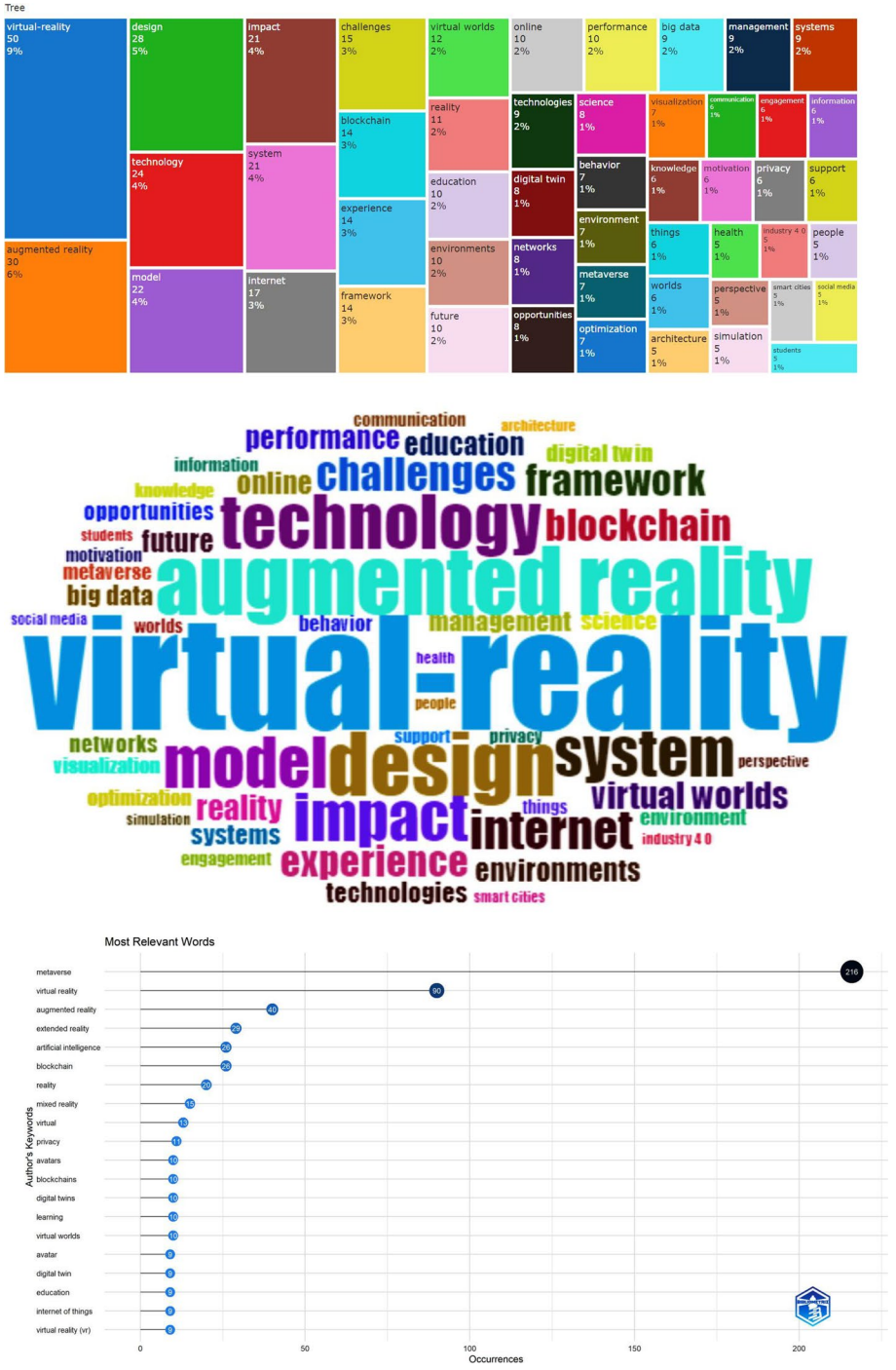

Fig. 10 Treemap chart of the 50 most frequently occurring "KeyWords Plus" terms and World cloud of the 50 most frequently occurring "KeyWords Plus" terms

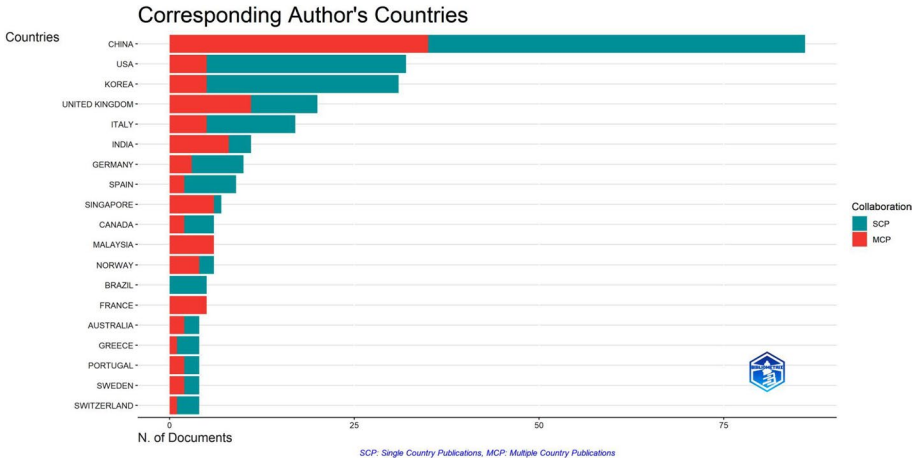

Fig. 11 Corresponding Author's Countries

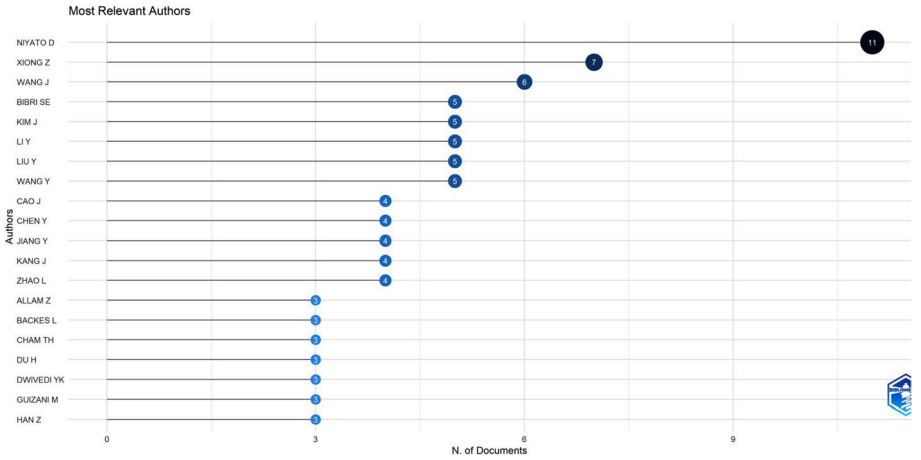

Fig. 12 Most relevant Authors

University (N = 11), and Gachon Univercity (N = 11) are listed as the top institutions (Fig. 14).

Country scientific production

The countries with the highest number of publications in the field of Metaverse are shown in Fig. 15. The number of research articles is represented by the blue color intensity on the map. According to this graph, China (134), USA (130), Korea (87), United Kingdom (72), India (45), and Singapore (48) are ranked as leading countries in terms of publications.

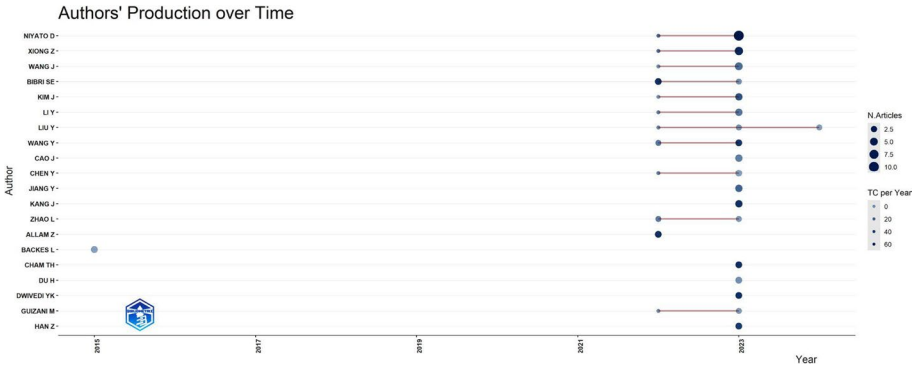

Fig. 13 The top 20 authors featured in research on the Metaverse

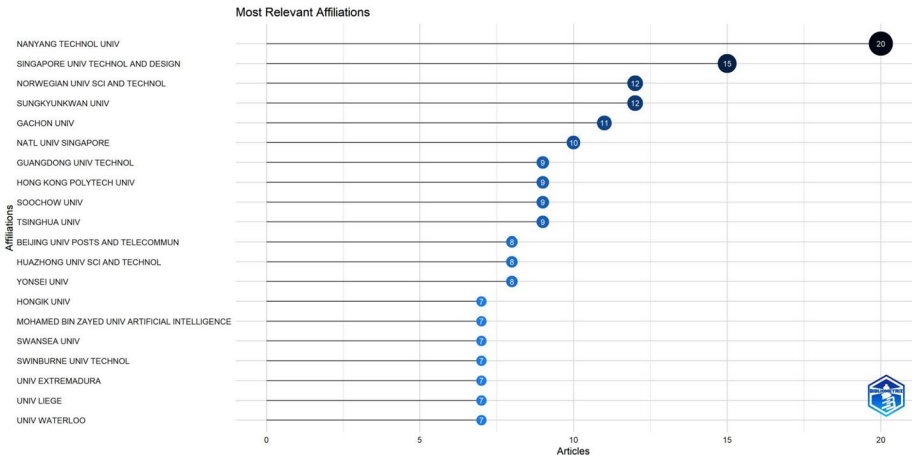

Fig. 14 Most relevant Affiliations

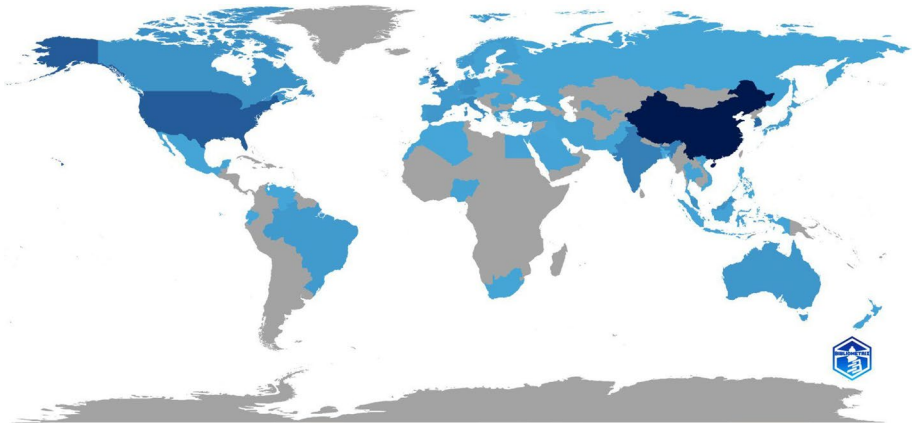

Fig. 15 Country Scientific Production

Fig. 16 Country Collaboration Map for Metaverse Articles

Country collaboration map

International research collaboration for articles on Metaverse is depicted in Fig. 16. The number of published articles is indicated by the intensity of the blue color on the map. The thickness of brown lines represents the intensity of collaboration based on frequency. While China stands out as the country with the strongest collaboration compared to other countries, the most collaborative countries are ranked as USA, Australia, and the United Kingdom, respectively.

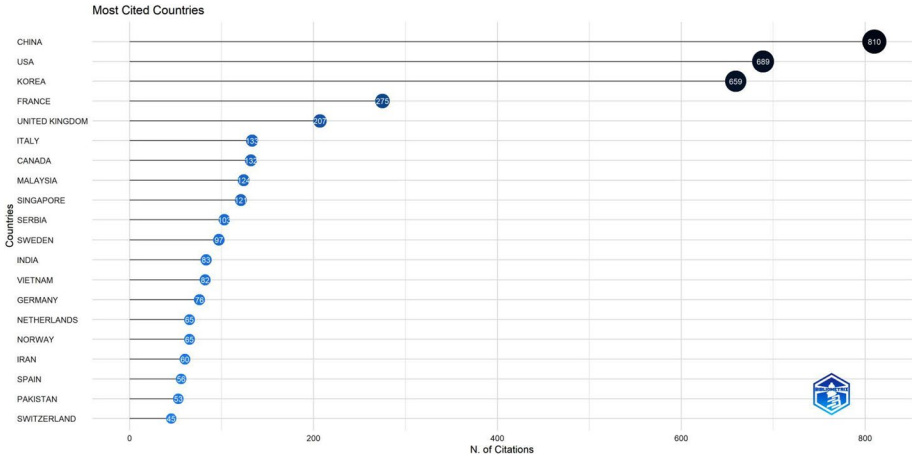

Fig. 17 Graph of Countries Receiving the Most Citations

Most cited countries

According to the graph shown in Fig. 17, the top five countries receiving the most citations are ranked as follows: China (810), USA (689), Korea (659), France (275), and United Kingdom (207).

Three-field plot

A three-field graph illustrating the relationship between keywords, countries, and journals is presented in Fig. 18. The height of the rectangular nodes within the graph represents the frequency of author keywords, keywords plus, and authors. The thickness of the lines between nodes represents the number of connections (Wang et al., 2022a, 2022b, 2022c).

Thematic map

To comprehensively capture the theme map of big data research, author keywords and index keywords from bibliographic records were clustered and classified by dividing them into two using the k-means and naive Bayes algorithms (Parlina et al., 2020). The revealed thematic map consists of thirteen clusters. For the clustering of metaverse topics, four categories are represented as clusters in different colors. In the first cluster represented by the green color, the terms 'virtual reality', 'augmented reality', and 'design' take prominence. In the blue cluster, terms such as 'impact', 'experience', and 'virtual worlds'' are observed. As seen in Fig. 19, the red cluster encompasses significant research topics.

Trend topics

The Trend topics chart presented in Fig. 20 is created based on Keywords Plus. In this context, the size of the circles within the graph indicates the frequency of the term, while the length of the lines represents how long this concept has been studied. In this

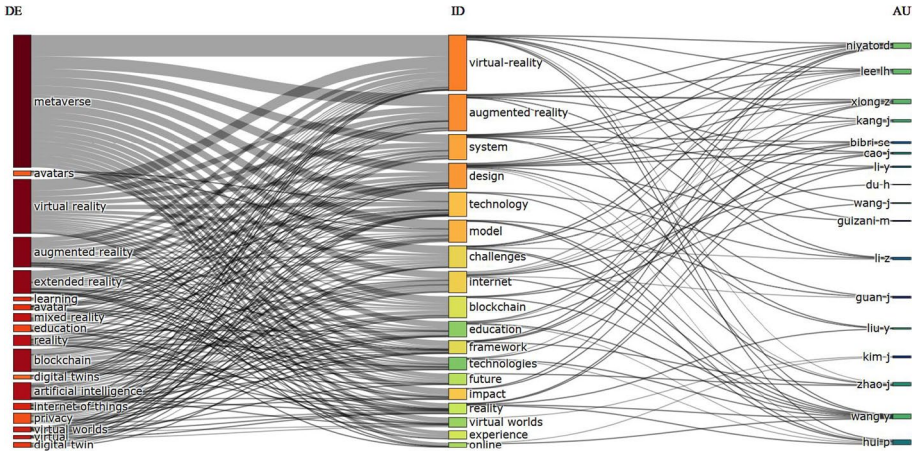

Fig. 18 Three-Field Plot showing the relationship between authors keywords (left), keywords plus (middle) and authors (right)

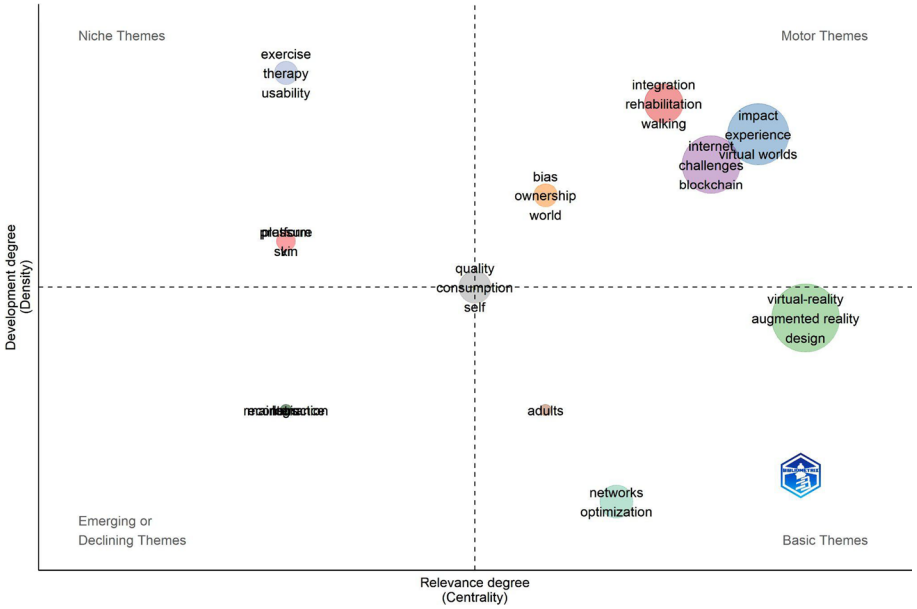

Fig. 19 Thematic map generated using author's keywords

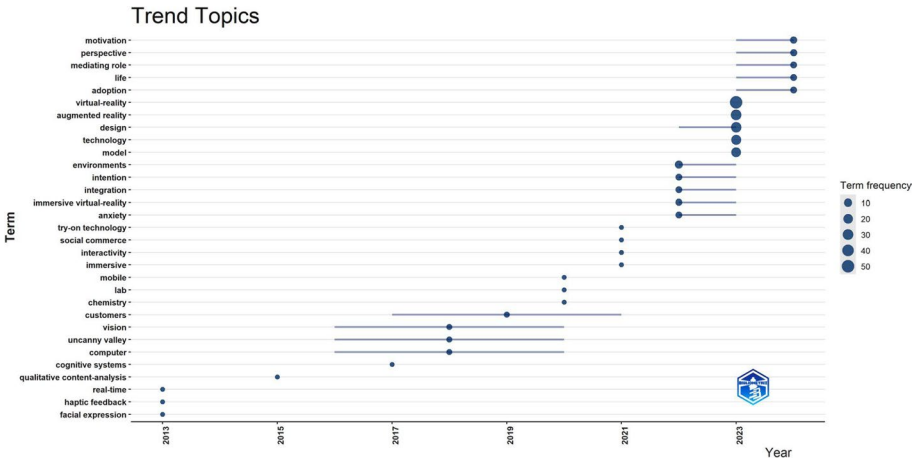

Fig. 20 Trend topics with Keywords Plus

context, the results of the analysis conducted to identify trend topics with Keywords Plus are presented in Fig. 20. Accordingly, virtual reality (f = 50), augmented reality (f = 30), technology (f = 24), design (f = 28), model (f = 22), and environments (f = 10) are determined as trend topics.

Table 1 Studies addressing the subject of architecture-metaverse

Research teams	References
Education	The contributions and challenges of the Metaverse to education (Ortega-Rodriguez, 2022); augmented reality and virtual reality applications (Algerafi et al., 2023); Collaborative learning in a virtual environment (Jovanovic & Milosavljevic, 2022); Interdisciplinary learning (Dreamson & Park, 2023); Types, potential, and limitations of the Metaverse (Kye et al., 2021); BIM integration (Bartels & Hahne, 2023); Virtual course outcomes (Hedrick et al., 2022); Literature review (Camilleri, 2023); Environmental conservation opportunities (Lo & Tsai, 2022); Advancements in educational technologies (Ruhimat et al., 2023); mixed reality course outcomes (Ricci et al., 2023); An innovative theoretical framework (Wang et al., 2022a, 2022b, 2022c); Augmented reality-based Metaverse (Onecha et al., 2023); Design education methodology (Chun, 2023); Literature review (Tlili et al., 2022); Development of intelligent systems (Sghaier et al., 2022); Learning contexts in the Metaverse (Schlemmer & Backes, 2015); Trends in metaverse changes (Chua & Yu, 2023); Metaverse e-learning (Wang et al., 2022a, 2022b, 2022c); Metaverse instructional quality (Tian et al., 2023); Augmented reality (Jin et al., 2022); A learning based incentive mechanism (Xu et al., 2022); Applying Metaverse in art and design teaching (Jin & Tiejun, 2023); Metaverse in different educational approaches (Kim et al., 2023); Biophilic organization of classroom environments in the Metaverse (You et al., 2023)
Building operation and maintenance	Smart building operation and maintenance (Casini, 2022)
Building evacuation	Efficient emergency evacuation scenario (Gu et al., 2023)
Building Information Modelling (BIM)	BIM applications (Liu et al., 2023); Learning and assessment of BIM (Bartels & Hahne, 2023); Integration of BIM and the Metaverse (Huang et al., 2022); Use of BIM in the construction industry (Shishehgarkhaneh et al., 2022)
Physical environment	The relationship between the physical environment and the metaverse database (Guan et al., 2023a, 2023b); Cross-reality hybrid spaces (Guan et al., 2023a, 2023b); Integration of the physical environment with asymmetric virtual space (Cho et al., 2022); Physical and virtual interfaces (Guan & morris, 2022)
Virtual space perception	Spatial bias (Chen et al., 2023); Virtual space design and nature (Xia & Pan, 2022); Sensory interaction (Dozio et al., 2022); Human interaction (Fang et al., 2023); Enhancement of virtual space perception (Sra, 2023); Museum visitor awareness (Türker & Işık, 2023); Virtual museum user experience (Choi & Kim, 2017); Virtual store atmosphere (Hassouneh & Brengman, 2015); Augmented reality spatial experience (Chung et al., 2024); Acoustic and auditory user experiences (Park et al., 2023); Evaluation of vitruvian principles (Ibanez & Naya, 2012); Virtual cave design (De francesco & Falcone, 2022); Evaluation of acoustic and auditory elements (Jot et al., 2021); Evaluation of virtual exhibition user experience (Wang et al., 2023); Virtual space tourism consumption patterns (Filimonau et al., 2022); Spatial cognition ability (Yu, 2021); Shadow and motion relationship (Hu et al., 2022); Perception of a biophilic approach in the metaverse (You et al., 2023)

Table 1 (continued)

Research teams	References
Cultural heritage	Virtual cultural heritage (Wu et al., 2022); Sustainability of cultural spaces (Su et al., 2023); Universal accessibility of cultural heritage (Franco et al., 2022); Perceptual evaluation of cultural heritage (Bigne et al., 2023); Cultural heritage studies (Lucchi, 2023)
Built environment/planning	Environment and public health (Koohsari et al., 2023); Built environment accessibility (Yang, 2023); Smart city ecosystem (Kuru, 2023); Proactive cultural education (Crolla & Goepel, 2022); Environmental consciousness (Reis & Camara, 2023); Urban planning opportunities (Hudson-Smith, 2022); Urban transportation planning in metaverse (Yu et al., 2023)
Smart city/GIS	Smart city user satisfaction (Susanpang et al., 2022); Gıs/gıs applications (Wortley, 2022); Potential contributions to smart cities (Allam et al., 2022); Impact on smart cities (Lv et al., 2022); Possibilities of gis application (Xu & Zeng, 2022); Advancing smart cities and urban development paradigms with metaverse (Bibri & Jagatheesaperumal, 2023)
Smart home	Smart home design (Yang et al., 2023)
Design and creativity	Relationship between augmented reality and design (Lyu et al., 2023); Design framework for augmented reality (Doma & Mert, 2022); Three-dimensional digital art from analog drawing (Ayiter, 2014); Collaborative design practices (Bardzell & Shankar, 2007); Stage design for music system (Zhou et al., 2022);Developing creative and critical design skills (Jin & Tiejun, 2023); virtual exhibition space design (Casillo et al., 2023); meta design of clinical environments (Oliveira et al., 2023)
Universal design/accessibility	Physically disabled individuals (Radanliev et al., 2023); Meta-learning system for disabled individuals (Sghaier et al., 2022); Augmented reality experiences for elderly individuals (Shah et al., 2022)
Sustainability	The impact of the sustainability concept (Jauhiainen et al., 2023)
Urban transportation systems	Potential impact of urban transportation systems (Zhang et al., 2023); Urban transportation planning in metaverse (Yu et al., 2023)
Post-occupancy evaluation	User satisfaction (Xu & Zhang, 2022)

Examination of publications in the field of architecture through content analysis

Among these studies, a total of 76 research papers were subjected to content analysis within the context of the relationship between architecture and the Metaverse, and the obtained data are presented in Table 1. Each study has been categorized according to thematic areas within the fields of architecture and design, revealing that the studies were produced in a total of 15 categories: education, building operation and maintenance, building evacuation, Building Information Modelling (BIM), physical environment, virtual space perception, cultural heritage, built environment/planning, smart city/GIS, smart home, design and creativity, universal design/accessibility, sustainability, urban transportation systems, and post-occupancy evaluation. In addition, brief information about the specific topics each study within the field of architecture and design focused on under each study theme has been provided. According to the content analysis conducted, it is evident that education

and virtual space perception themes are the most prevalent subjects of scientific research within disciplines related to architecture and design. The fact that the metaverse universe is a virtual fiction of the real world brings to the fore the question of how this universe is perceived by individuals. Consequently, the perception of virtual spaces becomes significant in studies related to the Metaverse. Furthermore, Table 1 indicates that the concept of the Metaverse is gaining importance in various themes related to architecture. It has the potential to be a promising research area in different fields such as different age groups, disability conditions, construction systems and technologies, cultural heritage, and transportation. The density and relevance of research themes in the fields of architecture and design align with the sustainable development goals related to the Metaverse. Themes such as education quality and sustainable cities and communities, as well as community objectives, are prominent in architectural studies as well.

Discussion and conclusion

This research, in general, reveals the overall trends in scientific research related to the Metaverse and specifically within the disciplines of architecture and design. The number of studies analyzed within the scope of the research has increased rapidly since 2021 and this momentum is expected to increase in the coming years. WoS categories such as Electrical-Electronic Engineering, Computer Science Information, and Telecommunications are prominent areas where the concept of the Metaverse is emphasized. In terms of sustainable development goals, topics like education quality, good health and well-being, and sustainable cities and communities are the focal points of research related to the Metaverse. When the document types are evaluated, it is seen that articles come to the forefront. The most frequently used keywords related to the Metaverse concept include virtual reality, augmented reality, design, system, and technology. In terms of the countries where the most studies are produced, China takes the lead, followed by countries such as the USA, Korea, and the United Kingdom. Additionally, the study provides data related to authors, citations, institutions, and journals.

The results of the bibliometric analysis conducted within the scope of the questions guiding the research are as follows.

RQ1: What is the development trend of publications in the Metaverse field over the years?

This study, which evaluates the research conducted between 2005 and 2023, shows that there is a similar trend with a small number of publications until 2021, but there has been a significant increase since 2021. It is predicted that the research on this subject increased rapidly in 2023 and will increase rapidly in the coming years.

RQ2: How are the relationships among stakeholders in this field, such as authors, institutions, and countries?

In the study, Nanyang Technology University, Singapore University of Technology and Design, Norwegian University, Sungkyunkwan University, and Gachon University stand out as research institutions related to the metaverse. In the study, Niyato was found to be the author with the highest number of publications. He is followed by Xiong Wang, Bibri, Kim, Li, Liu and Wang. In the study, China, the USA, Korea, the United Kingdom, India and Singapore are ranked as the leading countries in terms of publications. However, when the cooperation potentials of the countries are analyzed,

China stands out as the country with the strongest cooperation compared to other countries, while the countries with the most cooperation are the USA, Australia and the UK, respectively.

RQ3: What are the main keywords in the study domain, and how are they clustered?

In the publications examined in the study, it was determined that the keywords metaverse, virtual reality, augmented reality, extended reality, artificial intelligence, blockchain, reality, mixed reality, virtual were frequently used.

RQ4: What are the key elements, trends, and themes that characterize the global development of the Metaverse literature?

The prominent themes clustered in the study are "impact, experience, virtual worlds", "internet, challenges, blockchain", "integration, rehabilitation, walking" and "virtual-reality, augmented reality, design". The global collaborative network framework of Metaverse literacy and research needs to be strengthened. In the future, it is envisioned that this research area will further develop in sectors such as education, health, arts, commerce and entertainment. The results of this study are intended to serve as a reference for future applied research on the metaverse.

The particular focus of this study is to examine the themes in which the concept of the Metaverse has been explored within the disciplines of architecture and design. The content of architectural publications addressing the Metaverse has been analyzed in the study, revealing research trends in this field. Within this context, various themes related to the concept of the Metaverse have been explored in the disciplines of architecture and design. These themes include education, building operation and maintenance, building evacuation, Building Information Modelling (BIM), physical environment, virtual space perception, cultural heritage, built environment/planning, smart cities/GIS, smart homes, design and creativity, universal design/accessibility, sustainability, urban transportation systems, and evaluation in the usage process. Among these themes, education and virtual space perception stand out as the most researched areas.

In conclusion, this study aims to provide guidance for researchers by demonstrating how the concept of the Metaverse has shaped a research landscape within the disciplines of architecture and design over time.

This study presents a bibliometric and content analysis of a research conducted in the WoS database with the keywords "metaverse" AND "architect*" or "design" or "architectural studio" or "architectural education" or "building" or "architectural space" or "built environment" AND "virtual space" or "mixed reality" or "augmented reality" or "extended reality" or "cyberspace" or "virtual reality" or "virtual environment" or "virtual worlds" or "digital world". The study covers the use of metaverse in the field of architecture and design.

Although the concrete reality of the Metaverse has not materialized due to its conceptual novelty, its future prospects are interpreted as promising (Piñeiro-Chousa et al., 2024). In this context, researchers can contribute to this point by analyzing the theoretical foundations of the Metaverse in depth. In future studies, in order to obtain more systematic quantitative results on the metaverse, it is planned to expand the keywords, search different databases and include various contents in the study. In addition, it is planned to examine architectural content produced on digital architecture platforms related to metaverse. In order to expand the scope of the study, the relationship of the metaverse with different disciplines will be discussed.

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Declarations

Conflict of ınterest The authors whose names are listed above certify that they have NO affi liations with or involvement in any organization or entity with any fi nancial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-fi nancial interest (such as personal or professional relationships, affi liations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript. The authors declared that there is no conflict of interest.

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