ORIGINAL

Metaverse: an emerging research area

Metaverso: un área de investigación emergente

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ABSTRACT

Introduction: the progress of science and technology has allowed the advancement of informatics equipment, connectivity and virtuality, giving rise to new technologies such as metaverses.
Objective: to describe the trends in scientific output on the metaverse in Scopus and the Web of Science.
Method: bibliometric study of articles published in Scopus and the Web of Science concerning the metaverse in the period 1995 - 2022. Search formulas were used to retrieve the articles. Productivity indicators were studied.
Results: 76,82 % and 67,46 % of metaverse articles in Scopus and Web of Science respectively were published in the period 2020-2022. China and USA were identified as the most productive countries (Scopus: 17,82 % vs 16,17 %; Web Of Science: 19,69 % vs 17,81 %) and Sabancı Üniversitesi (n=28) and Chinese Academy of Sciences (n=26) as the most productive institutions. A predominance of original articles and articles in English was found; the most productive areas were Computer Science and Information Systems and the area of Engineering, Electrical and Electronics. In Scopus 37,38 % of the articles were found in open access and in WOS 40,21 %.
Conclusions: the metaverse is an emerging area of research, with China and the United States as leaders. The papers published in this area are mainly in English, as the lingua franca of science, characterized by the predominance of original studies and in fields such as computer science and engineering.

Keywords: Metaverse; Computer Communication Networks; Periodicals as Subject; Bibliometrics.

RESUMEN

Introducción: el desarrollo de la ciencia y la técnica han permitido el avance de los equipos informáticos, la conectividad y virtualidad, dando origen nuevas tecnologías como los metaversos.
Objetivo: describir las tendencias en producción científica sobre el metaverso en Scopus y la Web of Science
Método: estudio bibliométrico de los artículos publicados en Scopus y la Web of Science referente al metaverso en el periodo 1995 – 2022. Se emplearon fórmulas de búsqueda para la recuperación de los artículos. Se estudiaron indicadores de productividad.
Resultados: El 76,82 % y el 67,46 % de los artículos sobre metaverso en Scopus y Web of Science respectivamente se publicaron en el periodo 2020-2022. Se identificaron a China y Estados Unidos como los países más productivos (Scopus: 17,82 % vs 16,17 %; Web Of Science: 19,69 % vs 17,81 %) y como instituciones más productivas a la Sabancı Üniversitesi (n=28) y la Chinese Academy of Sciences (n=26). Se encontró predominio de originales y artículos en inglés; las áreas más productivas fueron Informática y Sistemas de Información y el área Ingeniería, Eléctrica y Electrónica. En Scopus el 37,38 % de los artículos se encontró en acceso abierto y en WOS el 40,21 %.

Conclusiones: el metaverso constituye un área de investigación emergente, donde China y Estados Unidos se muestras como líderes. La publicación en esta área se redacta principalmente en inglés, como lengua franca de la ciencia, caracterizada por el predominio de las investigaciones originales y en áreas como las ciencias Informáticas y las ingenierías.

Palabras clave: Metaverso; Redes de Comunicación de Computadores; Publicaciones Periódicas como Asunto; Bibliometría.

INTRODUCTION

Science and technique have progressed at a fast pace in the last years. Much of this development is due to the progress – as part of science and technique themselves – of the information and communication technologies.

The progress made in computer equipment and data computing, the access to the Internet and the internet of things have been conducive to humans evolving together with technologies, immersed in a biopsychosocial and digital environment. Nowadays, the processes conceived to be non-interconnected and non-digitized are scarce. This progress has favored the creation of concepts in keeping with the new needs and realities. Though some decades ago artificial intelligence,[1] the internet of things, virtual and immersive reality sounded futuristic, now they are part of the current reality.[2]

Metaverse combines the terms "meta", meaning virtuality and transcendence, with "verse", referring to the world and universe. This term was coined by Stepherson in 1992 in his science fiction novel and it is currently enunciated in a wide range of videogames and applications for leisure or sport training. Since 2021 it has acquired media exaltation due to the boost given by the technological giants, the elites of economic power and outstanding scientific centers for scientific knowledge.[3]

Though this word was initially used in science fiction, its concept has evolved and it is currently considered a virtual, highly immersive world making it possible to carry out leisure activities, socialization, study, work and research.[3] To this end, it includes elements like virtual reality and augmented reality as elements for more immersiveness. Sucari Sucari et al.[4] define the metaverse as an interaction between the real context and the immersive technologies such as virtual reality, augmented reality and mixed reality, in which the subject interacts through an avatar to develop many activities.

The analyses about this subject allow us to theorize about the contributions of metaverse to education,[5] health,[6] the economy and many other areas of knowledge.[7] Therefore, the study of the trends in research about this subject allow us to detect the current state, the areas of interest, as well as the countries and entities involved in the development of this incipient subject of science.

The metric disciplines of information (bibliometry, scientometry, infometrics and altmetrics) are key tools in the knowledge society because, drawing upon a multifactorial analysis, they make it possible to assess the state of the scientific output, either from a journal, an institution, a researcher, a topic or an area of knowledge.

In general, the metric indicators derived from articles (characteristics of manuscripts, editorial flows, citations) allow us to analyze phenomena such as trends in production, visibility and impact. In like manner, they enable us to identify weaknesses and opportunities for the editorial staffs and new areas of interest for researchers.

This piece of research was developed for the purpose of describing the trends in the scientific output about the metaverse in Scopus and Web of Science.

METHOD

We conducted an observational, descriptive, bibliometric study of the scientific output published on the metaverse in indexed journals in the databases Scopus (http://www.scopus.com/home.url) and Web of Science (https://www.webofscience.com/wos) until December 2022.

The following variables were studied:
- Number of documents (Ndoc): it contains the total scientific output, including all the typologies of documents, either citable or not;
- Scientific output by countries/regions: it makes reference to the scientific output generated by authors from a country or region;
- Scientific output by institutions: it makes reference to the scientific output generated by authors according to the institutional affiliations declared and quantified by the databases;
- Publishing language: it makes reference to the publishing language of the manuscript;
- Type of document: those documentary typologies defined by both Web of Science and Scopus were taken. Those categories allowing standardization were standardized and those that did not allow it were kept as they were;

- •   Scientific output by categories: those categories defined by both Web of Science and Scopus were taken when bringing together articles;
- •   Scientific output according to type of access of the articles: those categories of access under which the documents can be consulted were taken.

For information gathering, we accessed the databases on December 9, 2022. For each database we established an advanced search strategy, retrieving those articles containing "TITLE" in their title, "ABSTRACT" in their abstract and "KEYWORDS" in keywords, the word "metaverso" or its English translation "metaverse"; in the construction of the search formula, we used Boolean operators (AND and NOT).

RESULTS

During the period of study, a total of 971 pieces of research were found in Scopus and 659 in WoS. Both in Scopus and WoS the number of pieces of research on the metaverse showed a trend to increase, with a dizzy progress in the last two years, in which they rise to 746 in Scopus and 394 in WoS in 2022. These figures represent 76,82 % and 67,46 % of their respective totals in the last 28 years. These results are shown in figure 1.
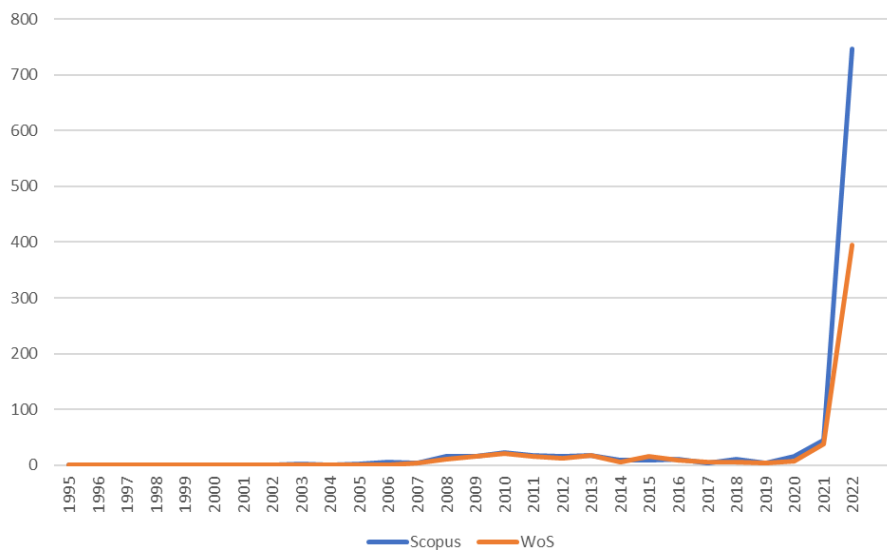
Figure 1. Distribution of metaverse studies in Scopus and WoS from 1995 to 2022

The analysis of the scientific output brought together according to countries showed China and the United States as maximum producers, where we found 17,82 % in Scopus and 19,69 % in WoS and 16,17 % in Scopus and 17,81 % in WoS respectively.

	Table 1. Distribution of articles by country of origin			
Rank	**Scopus**		**WoS**	
	Country	**Ndoc**	**Country**	**Ndoc**
1	China	173	China	115
2	United States	157	United States	104
3	South Korea	105	South Korea	71
4	United Kingdom	86	United Kingdom	50
5	Italy	42	Spain	34
6	Germany	41	Germany	26
7	Turkey	41	Italy	24
8	Japan	35	Turkey	23
9	Spain	32	Brazil	22
10	Taiwan	29	Japan	21

Figure 2 shows how, in contrast to the previous result, the countries in South America, Africa and, to a lesser extent, Northern Europe and Asia have a considerably smaller or null number of articles.

Figure 2. Geographical distribution of articles published in Scopus (A) and WoS (B)
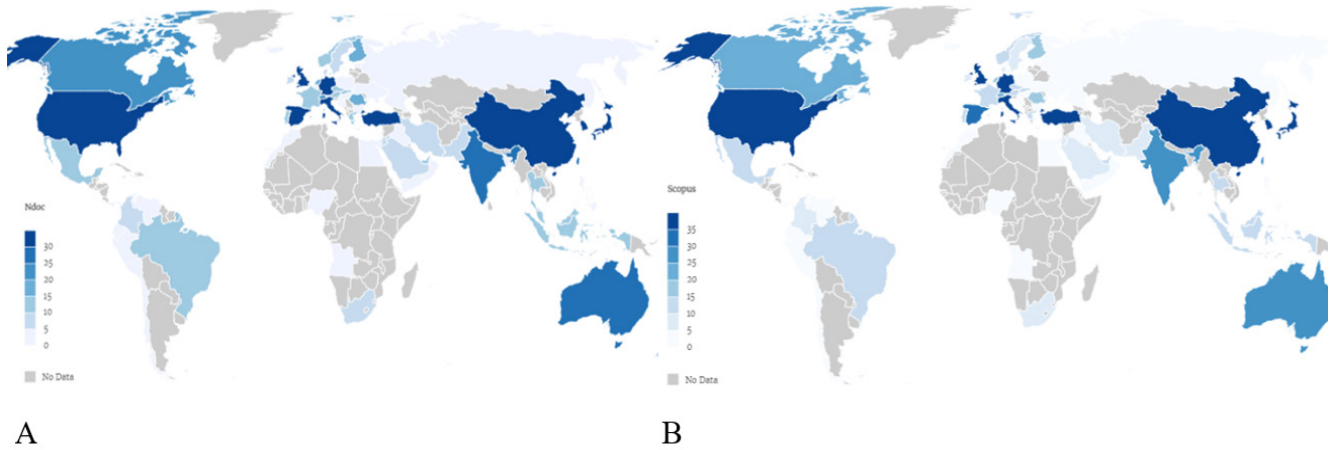
Sabancı Üniversitesi (n=28), the Chinese Academy of Sciences (n=26) and Nanyang Technological University (n=24) were found to be the most productive universities. The distribution of the most productive institutions, their countries and the output per database is shown in table 2.

Table 2. Affiliations to which the largest number of authors belonged				
Affiliations	**Country**	**Ndoc**	**Scopus**	**WoS**
Sabancı Üniversitesi	Turkey	28	17	11
Chinese Academy of Sciences	China	26	14	12
Nanyang Technological University	Singapore	24	15	9
Sungkyunkwan University	South Korea	21	12	9
Singapore University of Technology and Design	Singapore	15	9	6
South China University of Technology	China	15	8	7
Universidade do Vale do Rio Dos Sinos Unisinos	Brazil	14	0	14
University College London	England	14	7	7
Institute of Automation Chinese Academy of Sciences	China	13	8	5
National University of Singapore	Singapore	12	7	5
University of Southern California	United States of America	12	7	5

The most used languages were English in 94 % (n = 917) for Scopus and 83,15 % (n = 548) for WoS, followed by Chinese and Spanish with much smaller representation. These results are shown in table 3.

Table 3. Distribution of the number of articles according to the language of publication of the articles		
Language	**Scopus**	**WoS**
English	917	548
Mandarin Chinese	24	2
Spanish	13	21
Italian	4	0
Korean	4	3
Portuguese	4	5
German	3	3
French	1	1
Japanese	1	0
Russian	1	1

Original articles were the most common typology both in Scopus (46,03 %) and WoS (48,25 %) (table 4).

Table 4. Typology of published articles		
Article type	**Scopus**	**WoS**
Article	447	318
Conference Proceedings	370	143
Editorial material	37	57
Early access	0	54
Review article	57	35
Book chapters	28	20
Letter	16	16
Bibliographic review	0	9
Notes	11	3
Meeting Abstract	0	2
Art exhibition review	0	1
Book	4	1
Short communications	1	0
Total	971	659

Most of the published articles revolved around the area of Information Sciences (61,7 %; n = 600) in Scopus and 61,45 % (n = 405) in WoS, followed by electrical and electronic engineering. These results are shown in table 5.

Table 5. Category of published articles according to subject matter		
Categories	**Scopus**	**WoS**
Computer Science and Information Systems	600	405
Engineering, Electrical and Electronics	301	115
Social Sciences	220	21
Mathematics	123	2
Arts and Humanities	91	15
Business, Management and Accounting	88	52
Medicine	81	11

In Scopus, 37,38 % of articles were found in open access and 40,21 % in WoS. The open access *Gold* predominated both in Scopus (n = 189) and in WoS (n = 174) (table 5).

Table 5. Distribution of articles by type of open access		
Tipo de OA	**Scopus**	**WoS**
Total	363	265
Oro	189	174
Oro híbrido	32	21
Bronce	81	34
Verde	168	135

DISCUSSION

The journal in which an article is published has been considered almost as important as the results intended to be published. This is conditioned because journals have been cataloged and organized according to importance, based on indicators, therefore this factor influences the visibility of said results.[8]

There are two databases considered leaders regarding standards of quality, visibility and impact, channeling the main trends of science: Web of Science and Scopus. Consequently, authors tend to seek articles in these important databases, as the scientific validity seal is considered. In like manner, the academic world migrated

to publishing in journals indexed in these databases and the editors to developing policies allowing their publications to access these databases.[9]

The use and development of technologies has followed a trend to growth, without being a new phenomenon. And the fact is that every time a technology somehow enabling the daily activity of men is created, its use will progressively extend until another much more efficient appears. This dynamism guarantees the evolution of men a species.[10] Rather than a virtual universe, the metaverse is a technological tool with advantages applicable in different spheres of everyday life and, therefore, no wonder its use has such a speedy propagation demonstrated in the number of articles published about that subject and their annual quantitative growth.[11]

A noticeable fact is that, in general, there was an incipient publication in this area, with slight peaks caused by progress in infrastructure in this area as well as presence of economic crises with proven effect on the field of science. However, it was not until 2021 that an exponential growth of the volumes of scientific output began to be noticed.[12]

The speedy growth of publications, in the opinion of authors, related to the pandemic caused by COVID-19. During the COVID-19 stage, the governments, the institutions, the research and business sector had to undergo changes allowing them to develop their activities. To do so, the information and communication technologies and virtuality were a key link, fostering research and development of both software and hardware. Most of all, there was progress in the infrastructures making it possible to replace the need for social interactions caused by the isolation, hence metaverses became a valid alternative.

Consequently, COVID-19 favored the expansion and refinement of the computer and connectivity systems, interconnecting all areas of everyday practice[13] and establishing themselves as a fundamental core of the new biopsychosocial and technological being.

An increase in the scientific output since 2020 has been reported in several areas such as virtual reality[14] and information and communication technologies in education[15]; the growth of both areas is related to phenomena like COVID-19.

The most developed countries are currently the ones having better technological infrastructure, hence no wonder that China and the United States concentrate most of the global scientific output. These two characteristics are two processes with positive feedback: technological development potentiates economic development and the latter, in turn, determines how far technological development can go. These powers have achieved a technological expansion to all areas of human development.[16] Research on the metaverse as an emerging area are led by these countries for these reasons because, in turn, investing in areas with prospects is a smart bet for investors and researchers.

In contrast with the above, countries with fewer economic resources such as those in South America and Africa have very scarce or no publications about this subject in WoS and Scopus. Furthermore, this can be influenced by factors such as scarce investment by the Science and Innovation systems regarding scientific publication as well as lack of infrastructure to do research on this field. International cooperation can be a strategy to make up for this, where, by way of strategic agreements, human talent is exploited by other institutions having either the technology or the capacity to invest in technology, generating research and publications benefitting both actors.

It is convenient to point out that, although China and the United States lead the scientific output, only one institution of the latter is on the list of most productive institutions, showing dispersed pieces of research and non-specialization of some institution in this area. Likewise, a noticeable fact is that, in just a few decades, the People´s Republic of China passed from being a peripheral country to being the second economic, scientific and technological power at world level. Among other factors accounting for this fast rise in the global scenario are the decisions on scientific, technological and innovation policy.[17]

English was the language most used in the majority of the scientific articles, coinciding with the piece of research by Bojo Canales et al.[18] English has been considered to be the language of science, since the journals making up the core of a great deal of the areas of knowledge are edited in this language. The fact that Mandarin Chinese was the second most used language is understandable because a large number of the authors belong to the Chinese territory.

Informatics and Information Systems as well as *Electrical and Electronic Engineering* were the areas of knowledge under which the highest percentages of articles were published. This is an understandable fact because, first of all, metaverses are products generated in these areas. Likewise, innovation in infrastructure and software is necessary; therefore, the progress made in these matters is published as well as its relation to or repercussions on the development and/or evolution of metaverses.[19]

However, as mentioned above, some potential applications of the metaverse include virtual reality games, virtual events and lectures, virtual tourism, virtual education and training, virtual real estate and virtual socialization. Hence other areas of knowledge do research on these contexts, contributing publications on these subjects.[20]

It is noticeable that less than 45% of the articles in these databases were found in open access. Over the

last years, a movement in favor of open science has been formed as a way to do away with inequity as regards access to information. To this end, the academic publishing houses have largely turned from the subscription model into collecting the so-called article processing charges (APC) to researchers or institutions.

In like manner, the most productive period in the subject under study was marked by the presence of COVID-19. At this stage, as a contribution to the preservation of human health, many publishing houses and journals reduced or eliminated the costs relating to the publication of manuscripts on COVID-19, where many studies on the metaverse were favored.

This piece of research has a series of constraints, among them is the fact that only the publications in Scopus and WoS were studied and others such as SciELO, PubMed and Redalyc were excluded. Likewise, the metric indicators we used focused on describing the trends concerning publication, without studying the main actors or subjects involved in the scientific output at the level of authors, authorship networks and/or co-words. Nevertheless, it is a precedent to continue studying this fully emerging area.

CONCLUSIONS

The metaverse is an emerging research area where China and the United States are the leaders. The publications in this area are written mainly in English, as a lingua franca of science characterized by predominance of the original pieces of research and in areas such as information sciences and engineering sciences.

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FINANCING

CONFLICT OF INTEREST

No conflict of interest is declared.

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