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Bibliometric Mapping of Metaverse in Education

Nurullah Tas
Atatürk University, Turkey

Yusuf İslam Bolat
Kahramanmaraş İstiklal University, Turkey

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Nurullah Tas, Yusuf İslam Bolat

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Abstract

This research aims to create a bibliometric map of studies on the use of metaverse in education. We used the bibliometric mapping technique from an international viewpoint to assess trends in the area of metaverse research on education by disclosing the author, publication, keyword, journal, country, and citation factors. Most research on the topic was published in *Computers & Education*. Results indicate that *Hwang G.J*. is the most relevant author. *National Taiwan Normal University and National Taiwan University of Science and Technology* are the most relevant universities. *USA* has the most publications, co-authored publications, single-national publications, and cited articles overall. *China* is the nation with the greatest number of publications from other countries. *Denmark* is regarded as being at the top in the field of average citations per article. The terms *"augmented reality", "virtual reality"* and *"second life"* is sub-applications of the Metaverse environment, and are often used keywords. Over time, we can observe that prior research on “second life”, “virtual worlds” and “virtual environments” were gradually superseded by studies on “augmented reality”, “virtual reality”, “immersive virtual reality”, and “VR”. Over time, the phrase "metaverse" may become one of these tendencies. The papers in this research were subjected to cluster analysis. All clusters appear to involve *“virtual reality”*. Additionally, “augmented reality” was included in three clusters. Examining the measured network analysis of the authors reveals that they are clustered into five separate groups.

Introduction

With the development of technology in recent years, the concept of the "Metaverse" has gained importance. It is imperative to exist in the ever-changing technological world and to adapt to various technologies (Collins, 2008). In this context, it is necessary to follow and implement new technologies, especially in the field of education. With the new communication technologies, there should be significant changes in teaching methods for the transition from the 'passive receiver' state to the 'active participant' state, which occurs in the process of acquiring information (Hatavara & Mildorf, 2017; Suh & Ahn, 2022). Thanks to the new technology methods used in education systems, education and training have gained the opportunity to be carried out by students independently from physical environments.

Metaverse applications, which are one of the developing educational opportunities today, allow their users to have

virtual learning experiences interactively through their technological features (Dahan et al, 2022). It is necessary to provide high-quality data to feel that you are in an unreal environment and to interact with objects created with the help of computer programs (Dede et al, 2017). Depending on the quality of this visual and audio data, the user's feeling of being in that environment will be closer to reality (Kim et al, 2022).

Metaverse

The word metaverse is derived from the words meta (beyond) and the universe. Metaverse is a concept that allows the creation of virtual communities beyond commerce and entertainment. It is observed that there is a new generation of the Internet that includes a three-dimensional virtual space where users can interact through their avatars, and it is described as the "digital big bang" in cyberspace. It is stated that Metaverse aims to enable thematically interconnected inclusive experiences (Grings et al., 2009; Mystakidis, 2022). Zuckerberg (2021), CEO of Facebook Inc., whose name has recently changed to Meta, states that Metaverse will offer a sense of presence/side-by-side, as well as experiences such as meeting with friends/family, shopping, working, having fun, as well as today's computers and It means that different experiences can be experienced beyond how we think about phones and that teleporting can be carried out in the form of a hologram to the office, work or your family's house.

Metaverse in Education

It is possible to evaluate the Metaverse as a term that offers a new reality, a world of meaning, and learning opportunities from the perspective of education (Díaz, 2020). Metaverse offers a potential ground for new forms of learning. It is observed that Suzuki et al. (2020) have proposed a learning system for educational activities in the Metaverse. However, at the point of transferring education to the Metaverse, students and teachers need to have knowledge and guidance in the transition process. Parsons & MacCallum (2019) questioned the potential that Metaverse could offer for education; that even experienced teachers focused on the course content rather than augmented reality; points out that professional development processes should work if teachers realize the educational potential of augmented reality. The use of metaverse as an educational tool encourages students to do research in virtual environments and interact with information, thus increasing their interest and understanding, thus contributing to the creative learning process (Huang et al., 2010; Merchant et al., 2014).

It is seen that virtual environments, which provide students with rich perceptual clues and versatile feedback, can easily integrate with real environments, allow students to interact with the content, and facilitate the learning of concepts as a result of entertaining them while learning. Besides; along with the sense of being in the environment and the imagination of students, it helps students to construct knowledge by providing highly interactive learning experiences (Hwang & Chien, 2022). This technology allows students and objects in the virtual environment to interact with each other by providing the opportunity to bring together students from far distances in the virtual environment and by appealing to the senses such as sound, image, and touch (Hirsh et al., 2022). It is known that virtual reality technology, which creates new teaching environments today, is very useful especially in distance education if the necessary infrastructure is provided.

This technology can be used for educational purposes in areas that are very difficult to reach and experience physically (Mustafa, 2022). For example, it is used in virtual exercise applications in military training, especially in engineering training where nuclear studies will be carried out, in pilot and astronaut training with the creation of virtual cockpits, language learning, and practically on cadavers created in the field of medicine (Cheng, G. 2022; Dominguez-Noriega et al., 2011; Kanematsu et al, 2014; Lee et al., 2022; Locurcio, 2022; Potkonjak et al., 2016).

Students can find the chance to interact and communicate in the virtual environment with students in distant places where they cannot meet in the physical environment (Pena Arcila, 2014; Potkonjak et al. 2016). Thus, this technology can be used effectively in foreign language education, as it provides the opportunity to bring students from different countries together. In addition, students learn abstract concepts in the field of mathematics from virtual reality applications; They can also benefit from understanding historical events and earth formations in the fields of history and geography (Rospigliosi, 2022; Schlemmer & De Queiroz Lopes, 2011).

Importance of the Research and Research Questions

Lee (2021) states that there is a paradigm shift in information and communication technologies every ten years; He states that communication with computers in the 1990s, the web in the 2000s, and the mobile in the 2010s have changed and that the keyword of the paradigm of the 2020s is Metaverse. Even though the concept of the metaverse is increasing its popularity day by day, the discussions about it in the academic field are limited (Duan et al., 2021). It is possible to determine that Metaverse lays the groundwork for developments that will be closely related to educational studies (Sofianidis, 2022; Wu & Gao, 2022; Wu et al., 2013). Discussing the concept of the metaverse from an educational perspective will make it easier to offer explanations in terms of shedding light on this technology adaptation process and reservations.

Citation analysis provides valuable information for finding transdisciplinary similarities and differences across significant publications, influential journals, and influential authors (Biehl, Kim, and Wade, 2006). Citation analysis is regarded vital in terms of examining the historical state of the major topic of research in a subject, in addition to the comparative impacts of different studies (Donthu et al., 2021). Citation analysis assists researchers in identifying popular study subjects, techniques, and research trends, as well as understanding factors in significant concerns (Moral-Muñoz et al., 2020).

Although studies on the terms 2nd life, virtual reality, augmented reality, and virtual world, which are different applications of the metaverse, have been done frequently, examining these studies with bibliometric analysis within the scope of the metaverse will guide other researchers while working in the field. In this context, this research aims to create a bibliometric map of studies on the use of metaverse in education. For this purpose, answers to the following research questions were sought:

1. Which are the most relevant journals on metaverse in education?
2. Which are the most relevant authors on metaverse in education?
3. Which are the most relevant universities and countries on metaverse in education?

4. What is the citation status on metaverse in education?
5. What are the keywords and trending topics on metaverse in education?
6. How do clusters by authors coupling take shape in studies on metaverse in education?

Method

Research Design

This study aims to evaluate metaverse research on education. We used the bibliometric mapping technique from an international viewpoint to assess trends in the area of metaverse research on education by disclosing the author, publication, keyword, journal, country, and citation factors. Bibliometric mapping is a visual depiction of the connections between disciplines, domains, specific publications, and authors (Donthu et al., 2021). Bibliometric studies allow for the detection of trends in the area by quantifying and assessing some of the aspects of research in a specific field (Ahmi, 2022). Following up on studies, researchers, institutions, and scientific flow relevant to the determined scientific issue is possible with bibliometric analysis (Martí-Parreño et al., 2016).

Obtaining the meta-data collection

First of all, we queried The Web of Science (WoS) database with the query (“Metaverse”). Then we make a word cloud from keywords from downloaded meta-data. The terms Metaverse, Second Life, Virtual Reality, Virtual Worlds and augmented reality turned out to be prominent keywords. After emerging from these keywords, we queried The Web of Science (WoS) database with the query (“Metaverse” OR “Second Life” OR “Virtual Reality” OR “Virtual Worlds” OR “augmented reality”). We filtered our query by selecting educational research from the WOS science categories, articles from the document type category, and English from the languages category. As of June 2022, a total of 2638 metadata sets were obtained without year, and index limitations. Because WoS permits up to 1000 results to be downloaded at once in the "BibTeX" format, the meta-data set consists of three independent "BibTeX" files. We merged these three “BibTeX” in Visual Studio Code Editor. We gave the various descriptive data about the studies obtained in Table 1.

Table 1. Descriptive Data of Obtained Studies

Description	Results
Timespan	1994:2022
Sources (Journals, Books, etc.)	478
Average years from publication	6.81
Average citations per document	14.82
Average citations per year per doc	1.961
Authors of single-authored documents	224
Authors of multi-authored documents	2295
Documents per Author	0.437
Authors per Document	2.29
Co-Authors per Documents	2.82

When we examine Table 1, we see that the studies on the subject were published in 302 different journals between 1994-2022. An average of 6.81 articles are published per year on the subject. The average number of citations for these articles is 14.82. Each article receives an average of 1.96 citations per year. The number of articles with a single author is 224. The number of articles with multiple authors is 2295. There are 0.43 articles per author. There are 2.29 authors per article. The number of Co-Authors per Article is 2.82. We can see the annual scientific production in Figure 1.

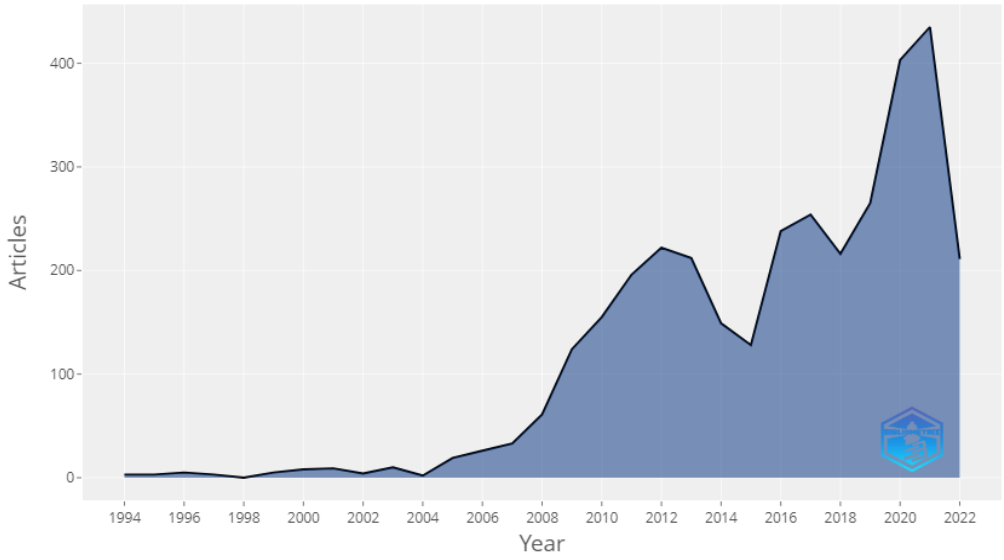

Figure 1. Annual Scientific Production

Data Analysis

Patterns based on mathematical correlations were identified using meta-data from the papers included in the study and visualization approaches based on bibliometric data. Using the meta-data collection, R Studio software and bibliometrics package were used to perform co-authorship, bibliographic coupling, keyword co-occurrence, and citation analyses. To expose more significant maps, the threshold (limit value selected to generate more meaningful maps) was employed. The relationship between the elements (publication, journal, author, etc.) is determined by the number of resources they share in bibliographic coupling. In other words, a reference to the same publication in two separate sources is termed bibliographic coupling. Keyword co-occurrence analysis displays the evolution of the study field through time (Donthu et al., 2021). It is a useful tool for spotting hotspots in a variety of disciplines (Ahmi, 2022).

Results

Most Relevant Journals

There are 3623 articles in 478 journals on the use of metaverse in education in the Web of Science database. The 20 journals with the highest number of publications are given in Table 2. Among the top 20 journals, Computers & Education published the most studies on the subject (ArtN=275). This number constitutes approximately 16% of the number of articles published in the first 20 journals. This journal also has the highest total citation score

(TC=20.495). It is also the most-cited journal on the use of metaverse in education (CiteN=7.685).

Table 2. Top 20 Journals with the Most Articles

Journal	ArtN*	CiteN*	*h*-index	*g*-index	TC*
Computers & Education	275	7.685	80	132	20.495
Interactive Learning Environments	211	1.269	30	46	3.206
International Journal of Emerging Technologies in Learning	155	318	14	22	924
British Journal of Educational Technology	147	2.626	38	66	4.891
Education and Information Technologies	122	94	14	20	651
Journal of Computer Assisted Learning	82	1.061	21	42	1.922
Educational Technology & Society	78	1.264	26	48	2.445
Journal of Educational Computing Research	76	96	15	20	712
Education Sciences	65	116	7	12	229
Etr\&D-Educational Technology Research and Development	63	1.313	18	36	1.370
Australasian Journal of Educational Technology	57	23	17	25	832
Bmc Medical Education	57	137	14	25	683
Journal of Science Education and Technology	54	1.100	16	49	2.420
Ieee Transactions on Learning Technologies	50	312	18	34	1.229
Simulation & Gaming	45	110	9	14	247
Techtrends	44	412	11	26	751
Turkish Online Journal of Distance Education	41	46	6	8	94
Research in Learning Technology	38	127	9	17	344
Eurasia Journal of Math. Science and Technology Education	36	308	15	25	711
Interaction Design and Architectures	36	24	5	6	61

*ArtN= Article Number, *CiteN=Citation Number, *TC=Total Cite

Considering the citation, TC and number of articles, other prominent journals include British Journal of Educational Technology (ArtN=147, CiteN=2.626, h-index=38, g-index=66, TC=4.891), Interactive Learning Environments (ArtN=211, CiteN=1.269, h-index=30, g-index=46, TC=3.206) Educational Technology & Society (ArtN=78, CiteN=1.264, h-index=26, g-index=48, TC =2.445), Journal of Computer Assisted Learning (ArtN=82, CiteN=1.061, h-index=21, g-index=42, TC=1.922). According to Bradford's Law which shows the core journals, 9 journals constitute the core resources of the field (see Figure 2).

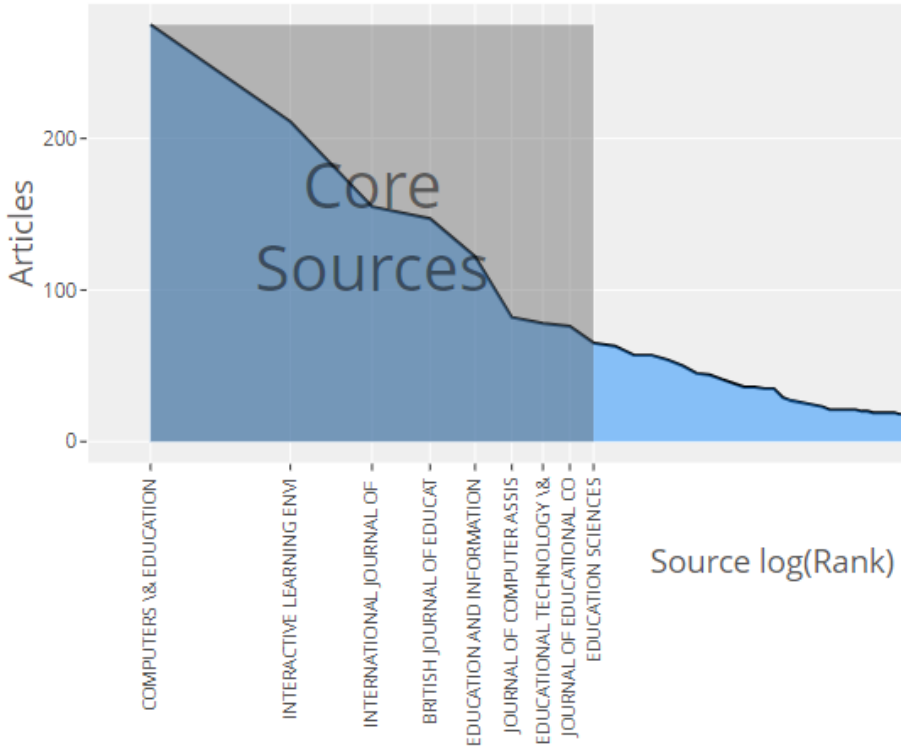

Figure 2. Bradford's Law

Most Relevant Authors

5920 researchers are working on the metaverse in education in the Web of Science database. Data on publication years, the number of citations, index scores, and TC scores of the 20 authors who published the most on the subject are presented in Table 3.

Table 3. Top 20 Authors with the Most Articles

Authors	ArtN	Pub. Year	CiteN	CPY*	*h*-index	*g*-index	TC
Hwang G.J.	37	2012-2022	454	45,40	19	30	1.691
Tsai C.C.	27	2001-2022	277	13,20	15	27	969
Makransky G.	26	2018-2022	548	137	15	26	1.371
Nelson B.C.	23	2010-2020	0	0,00	2	7	120
Erlandson B.E.	22	2012-2014	0	0,00	1	1	6
Ke F.	21	2013-2021	2	0,25	10	16	272
Chen C.H.	20	2010-2021	136	12,37	12	18	694
Lan Y.J.	19	2013-2020	190	27,20	15	19	599
Cheng K.H.	18	2014-2022	104	13,00	10	16	423
Yilmaz R.M.	18	2013-2022	136	15,10	11	17	420
Jong M.S.Y.	17	2020-2021	96	96,00	11	17	407
Passig D.	17	2001-2016	136	9,10	8	16	263
Marques M.M.	15	2017-2021	15	3,80	5	6	49

Authors	ArtN	Pub. Year	CiteN	CPY*	*h*-index	*g*-index	TC
Childs M.	14	2010-2014	0	0,00	5	5	46
Lorenzo G.	14	2013-2022	92	10,20	8	9	331
Wang Y.	14	2009-2022	1	0,10	9	12	380
Gee J.P.	13	2009-2017	11	1,40	4	5	51
Pombo L.	13	2017-2021	15	3,80	5	6	47
Savin-Baden M.	13	2010-2016	24	4,00	7	12	155
Thomas M.	13	2013-2018	0	0,00	3	4	21

CPY= Citations per Year

When the table is examined, Hwang G.J. is the most influential writer. It is seen that the researcher published the most articles (ArtN=37), index scores (h-index= 19, g-index=30), and TC score (TC=1691) were the highest. The most cited author is Makransky G. (CiteN=548). Jong M.S.Y.(CPY=96.00) is the most cited author per year. The distribution of the authors' studies by year is given in Figure 3.

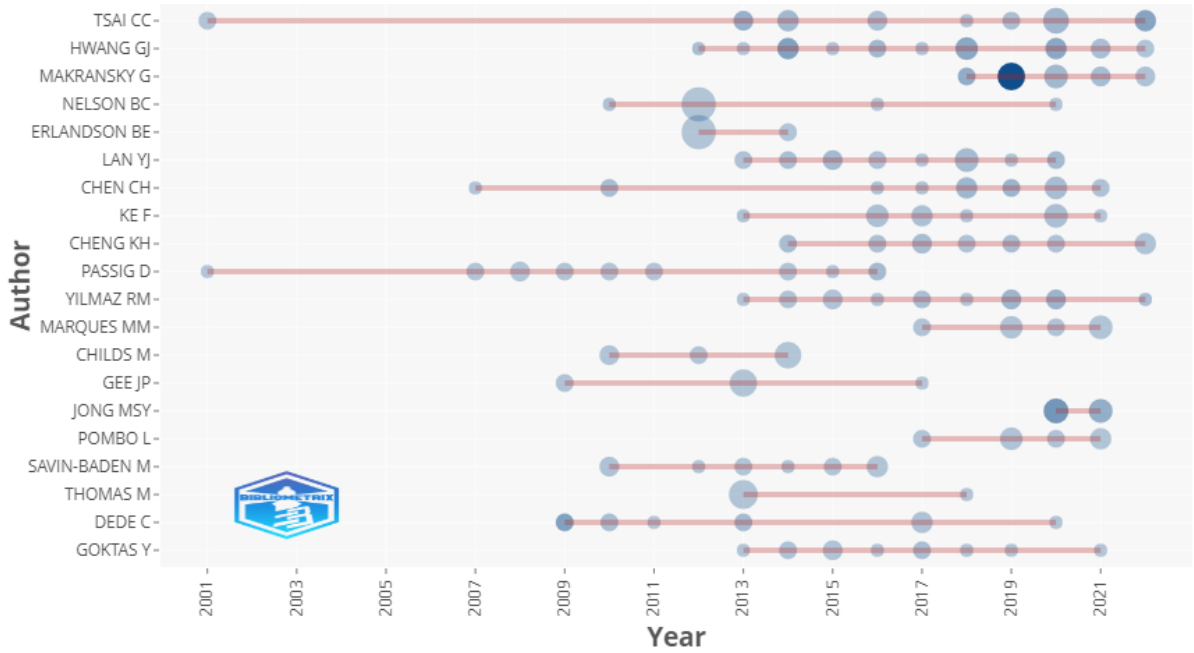

Figure 3. Top Authors' Production over Time

In the early 2000s, Tsai C.C. and Passig D. are seen to be working. It is seen that the number of authors working after 2010 has increased. In 2022, when this study was conducted, research published by Tsai C.C., Hwang G., Makransky G., Cheng K.H., and Yilmaz R.M. stands out.

Most Relevant Universities and Countries

The data on the 20 universities that publish the most and the number of articles is presented in Table 4. These 20 universities have published a total of 1568 articles on the subject.

Table 4. Top 20 Universities with the Most Articles

Affiliations	ArtN
Natl. Taiwan Normal Univ.	286
Natl. Taiwan Univ. Sci. and Technol.	132
Open Univ.	92
Arizona State Univ.	83
Chinese Univ. Hong Kong	83
Univ. Copenhagen	75
Macquarie Univ.	74
Natl. Cent. Univ.	67
Univ. Alicante	67
Univ. Aegean	65
Nanyang Technol. Univ.	64
Ataturk Univ.	63
Curtin Univ.	59
Coventry Univ.	56
Anadolu Univ.	54
Beijing Normal Univ.	53
Florida State Univ.	52
Univ. North Texas.	50
Univ. Texas. Austin.	47
Texas A and M. Univ.	46

The two universities that publish the most are in Taiwan. The number of publications made by National Taiwan Normal University (ArtN=286) and National Taiwan University of Sciences and Technologies (ArtN=132) universities constitutes 27% of the number of publications made by the first 20 universities. The relevant data according to the number of publications based on countries, the number of responsible authors, the status of the study from one or more countries, and the number of citations is presented in Table 5.

Table 5. Top 20 Countries with the Most Articles

Country	ArtN	CAAN*	SCP*	MCP*	TCN*	AAC*
USA	2687	840	780	60	17.138	20,40
China	2007	602	511	91	12.868	21,40
UK	897	287	224	63	5.308	18,50
Australia	635	198	167	31	4.512	16,00
Spain	607	191	143	48	3.159	23,62
Turkey	524	180	160	20	2.068	11,49
Canada	325	87	78	9	727	8,36
Italy	270	80	70	10	1354	16,93
Greece	251	79	74	5	1446	18,30

Country	ArtN	CAAN*	SCP*	MCP*	TCN*	AAC*
Germany	198	63	50	13	710	11,27
Finland	170	48	39	19	344	7,16
Netherlands	169	47	40	7	602	12,80
Denmark	158	47	30	17	1555	33,10
South Korea	135	40	26	14	712	17,80
Malaysia	119	37	31	6	230	6,20
Cyprus	116	32	25	7	225	7,03
Israel	115	41	37	4	760	18,53
France	109	29	23	6	173	5,96
Russia	105	24	22	2	10	0,41
New Zealand	104	36	28	8	374	10,40

*CAAN= Corresponding Author Article, *SCP=Single Country Publication, *MCP=Multiple Country Publication, *TCN= Total Citations Number, *AAC= Average Article Citation

Accordingly, the USA has the highest number of publications, co-authored publications, single-national publications, and cited publications (ArtN=2687, CAAN=840, SCP=780, TCP=17.138). The country with the highest number of multinational publications is China (MCP=91). In the area of average citations per publication, Denmark (AAC=33.10) is seen to be at the top (see Table 5).

Citation Status

The data on the number of citations of the articles at the global and local levels are presented in Table 6. The most cited article globally is Wu's article titled "Current Status, Opportunities, and Challenges of Augmented Reality in Education" published in Computer & Education in 2013 (GC=808). This article is also the most cited locally (LC=288).

Table 6. Top Cited 20 Papers

Paper	DOI	GC*	LC*	LC/GC (%)
Wu H.K., 2013, Comput. Educ.	10.1016/j.compedu.2012.10.024	808	288	35.64
Hanus M.D., 2015, Comput. Educ.	10.1016/j.compedu.2014.08.019	640	4	0.63
Merchant Z., 2014, Comput. Educ.	10.1016/j.compedu.2013.07.033	556	218	39.21
Dunleavy M., 2009, J. Sci. Educ. Technol.	10.1007/s10956-008-9119-1	525	221	42.10
Margaryan A., 2011, Comput. Educ.	10.1016/j.compedu.2010.09.004	437	5	1.14
Di Serio A., 2013, Comput. Educ.	10.1016/j.compedu.2012.03.002	434	164	37.79
Warburton S., 2009, Br. J. Educ. Technol.	10.1111/j.1467-8535.2009.00952.x	338	0	0.00
Klopfer E., 2008, Etr\&D-Educ. Tech. Res. Dev.	10.1007/s11423-007-9037-6	329	0	0.00
Annetta L.A., 2009, Comput. Educ.	10.1016/j.compedu.2008.12.020	326	21	6.44
Lee K., 2012, Techtrends	10.1007/s11528-012-0559-3	295	75	25.42

Paper	DOI	GC*	LC*	LC/GC (%)
Potkonjak V., 2016, Comput. Educ.	10.1016/j.compedu.2016.02.002	290	40	13..80
Huang H.M., 2010, Comput. Educ.	10.1016/j.compedu.2010.05.014	273	106	38.83
Tuezuen H., 2009, Comput. Educ.	10.1016/j.compedu.2008.06.008	268	0	0.00
Gavish N, 2015, Interact. Learn. Environ.	10.1080/10494820.2013.815221	256	0	0.00
Makransky G., 2019, Learn. Instr.	10.1016/j.learninstruc.2017.12.007	250	146	58.40
Dickey M.D., 2005, Br. J. Educ. Technol.	10.1111/j.1467-8535.2005.00477.x	247	0	0.00
Hew K.F., 2010, Br. J. Educ. Technol.	10.1111/j.1467-8535.2008.00900.x	243	0	0.00
Jarmon L., 2009, Comput. Educ.	10.1016/j.compedu.2009.01.010	236	100	42.37
Wojciechowski R., 2013, Comput. Educ.	10.1016/j.compedu.2013.02.014	231	93	40.26
Heradio R., 2016, Comput. Educ.	10.1016/j.compedu.2016.03.010	229	17	7.42

*GC= Global Cite, *LC=Local Cite

Six articles were not cited locally. The highest rate of citations locally belongs to Makransky's article titled "Adding Immersive Virtual Reality to a Science Lab Simulation Causes more Presence but Less Learning" published in 2019 (LC/GC (%) =58.40). The data on the total number of citations received by the studies and the annual average number of citations are presented in Table 7.

Table 7. Annual Average Number of Citations per Article

Year	N	MeanTCperArt	MeanTCperYear	CitableYears
1994	3	9	0.32	28
1995	3	142.33	5.27	27
1996	5	13.4	0.51	26
1997	3	1	0.04	25
1998	0	0	0	0
1999	5	4.2	0.18	23
2000	8	16.37	0.74	22
2001	9	21.55	1.02	21
2002	4	19.75	0.98	20
2003	10	23.4	1.23	19
2004	2	56	3.11	18
2005	19	73.84	4.34	17
2006	26	44.26	2.76	16
2007	33	44.87	2.99	15
2008	61	45.32	3.23	14
2009	124	47.28	3.63	13
2010	155	31.82	2.65	12
2011	196	18.80	1.70	11
2012	222	15.73	1.57	10
2013	212	26.72	2.96	9

Year	N	MeanTCperArt	MeanTCperYear	CitableYears
2014	149	30.79	3.84	8
2015	128	30.02	4.28	7
2016	238	19.11	3.18	6
2017	254	14.56	2.91	5
2018	216	14.97	3.74	4
2019	265	13.72	4.57	3
2020	403	7.61	3.80	2
2021	435	3.50	3.50	1
2022	211	2.32		0

Articles on the subject started to be published in 1994. When the annual average number of citations is examined, it is seen that the average number of citations per article (5.27) was the highest in 1995. It is seen that the average number of citations is high in 2005, 2015, and 2019.

Keywords and Trend Topics

The data in KeyWords Plus are terms or phrases that appear often in the titles of an article's references but not in the title of the article itself. KeyWords Plus extends the efficacy of cited-reference searches by searching across disciplines for all papers that have cited references in common (Clarivate, 2022). In Figure 4, the 50 most used Keywords Plus are given.

Figure 4. Word Cloud of Keywords Plus

The most used keyword is “education(f=567)” because it is the main scope. It is noteworthy, however, that the word "Metaverse" is absent in this word cloud. However, it is seen that the terms "augmented reality (f=219),

virtual-reality (f=178), 2nd life (f=148)", are sub-applications of the Metaverse universe, and are among the frequently used keywords. The word cloud with the keywords of the authors is given in Figure 5.

Figure 5. Word Cloud of Authors' Keywords

According to this word cloud, the most used words are “virtual-reality (f=833), augmented reality (f=592), education (f=210), 2nd life (f=148), learning (f=199), virtual worlds (f=162)”. Trends by year are presented in Figure 6.

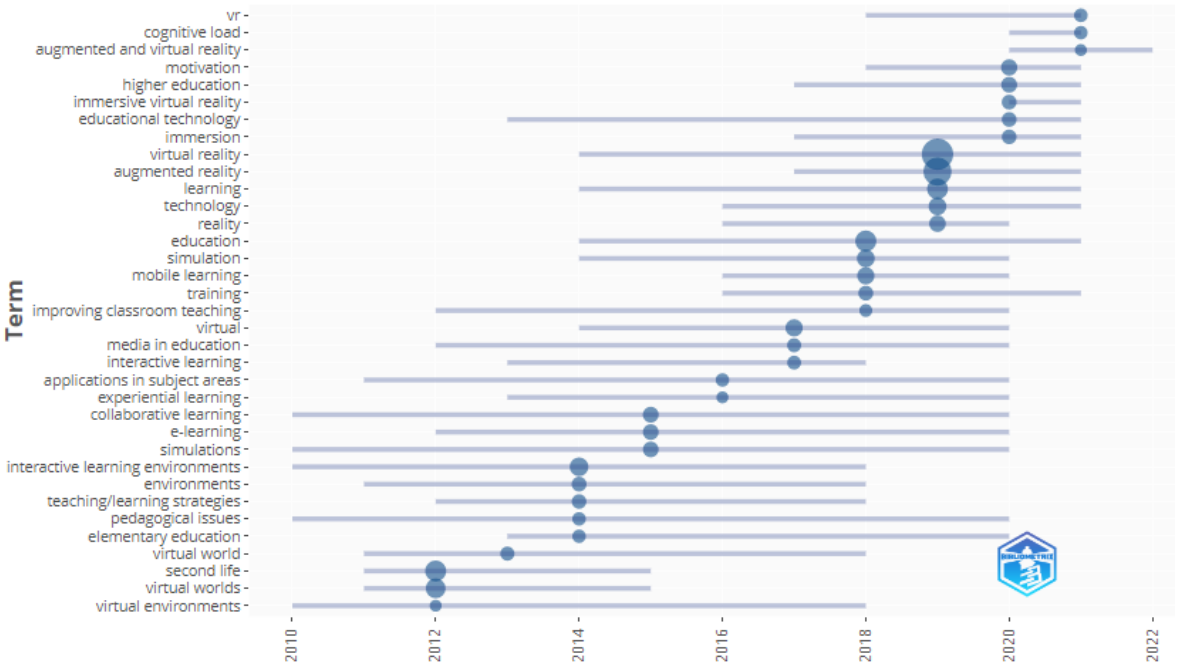

Figure 6. Trend Topics

When the figure is examined, we see that the previous studies on 2nd life, virtual worlds, and virtual environments were replaced by studies such as augmented reality, virtual reality, immersive virtual reality, and VR over time. The term metaverse may become one of these trends over time.

Clusters by Authors Coupling

Cluster analysis was performed on the articles in this study. Author key terms, the number of clusters, centricity data, and impact data in these clusters are presented in Table 8.

Table 8. Clustering Analysis

Label	Conf(%)	Group	Freq.	Centrality	Impact
Augmented Reality	66.9				
Virtual Reality	46.2				
Interactive	79.4	1	51	0.71	3.06
Learning Environments	68.6				
Learning Teaching/Learning strategies	94.1				
Virtual reality	26.6				
Learning	25.5				
Simulation	57.1	2	33	0.74	2.65
Multimedia Learning	100				
Presence	66.7				
Virtual Reality	19.7				
Virtual Worlds	65.2				
Collaborative Learning	54.5	3	30	0.46	2.54
Situated Learning	90.9				
Augmented Reality	6.9				
Augmented Reality	21.5				
Virtual Reality	7.5				
Interactive Learning Environments	9.5	4	22	0.73	2.44
Research	75				
3d Virtual Worlds	50				

While performing the cluster analysis, references, global citation scores, and author keywords were chosen and the minimum number of clusters was taken as 5. Virtual reality appears to be included in all clusters. Augmented reality also found its place in three clusters (see Figure 7). The network map of the authors in these clusters is presented in Figure 7.

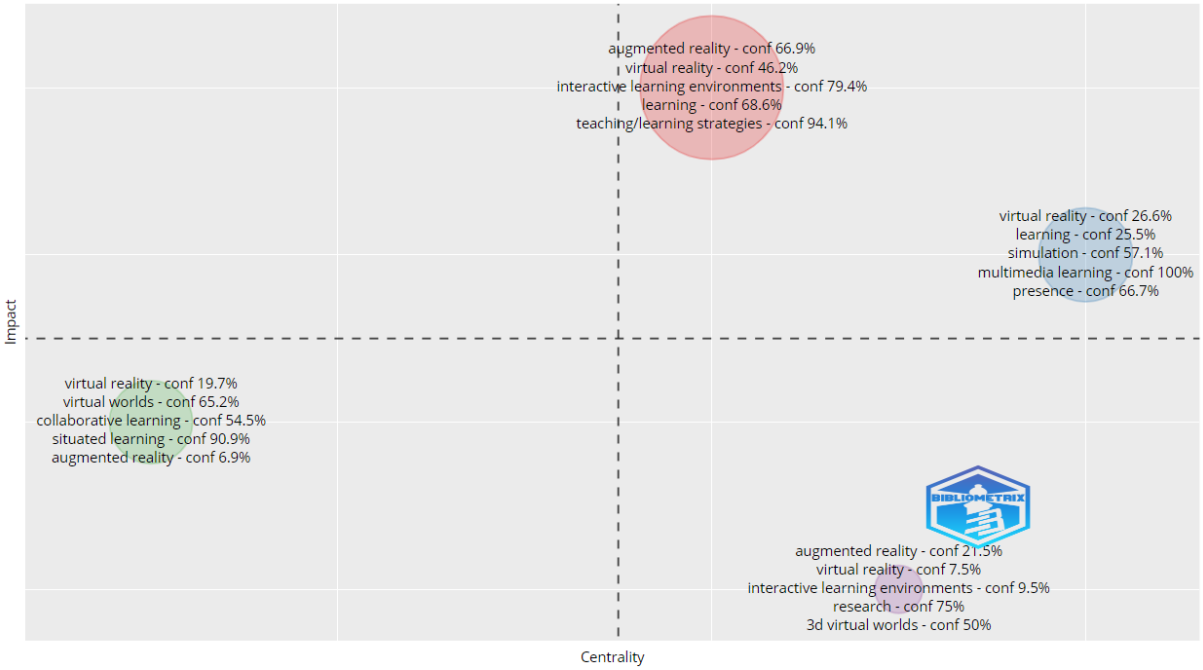

Figure 7. Clustering Map

Figure 8 shows the relationship between the authors using the network analysis method. Each different color was clustered by the program by establishing the connection between the authors. When the author network is examined with the Rstudio program, the most productive authors of the green cluster are Bower M. and Ke F. In the red-colored cluster; Hwang G.J., Chen C.H. and Tsai C.C. in the purple cluster; Yilmaz R.M., Göktas Y., and in the blue cluster Makransky G. and Cheng K.H. stands out. When the Authors measured network analysis is examined, it is seen that they are gathered in five different clusters.

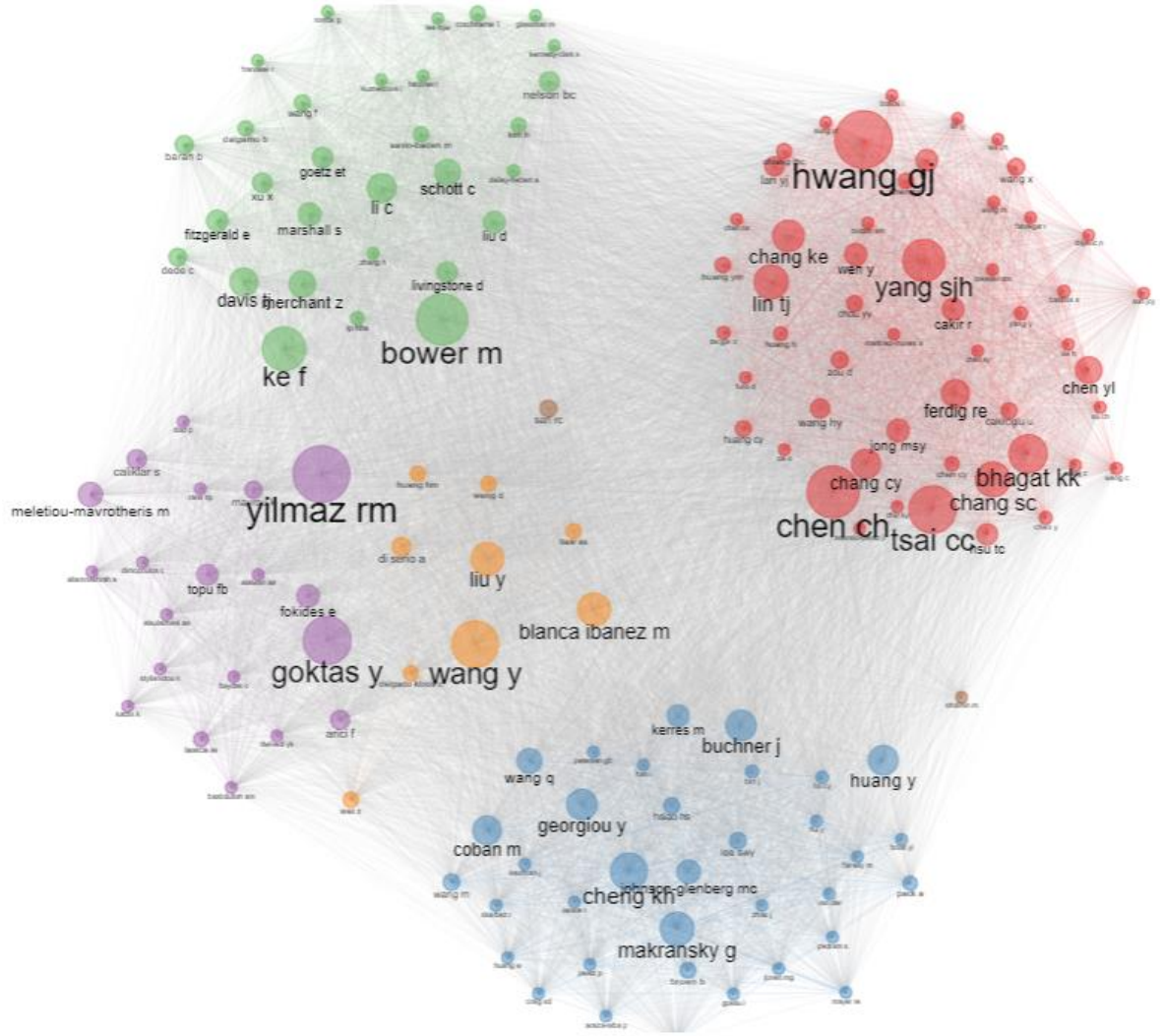

Figure 8. Clustering Network of Authors

Discussion

This study aims to examine the studies on the metaverse in education from a bibliometric perspective. For this purpose, the journals, authors, universities, and countries that published the most on the subject were determined. The citation status of publications has been extensively discussed. Keywords and trending titles related to the metaverse were examined in the training. Author studies were examined with the cluster by the authors' coupling method. Most research on the topic was published in Computers & Education. Calabuig-Moreno et al. (2020) in their general bibliometric analysis with a focus on virtual and augmented reality, found Computers & Education

as one of the journals with the highest number of publications citations and impact factors. This journal on using the metaverse in teaching has received the most citations. Bradford's Law states that the primary sources in the area are nine journals. Other notable journals, in terms of citations, total, and the number of articles, are the British Journal of Educational Technology, Interactive Learning Environments, Educational Technology & Society, and Journal of Computer Assisted Learning. Looking at these journals, it can be said that journals that focus on instructional technologies give more weight to the subject.

Results indicate that Hwang G.J. is the most relevant author. It can be observed that the researcher published the most publications, and had the highest index scores, and the highest TC score. Makransky G. has received the most citations. Jong M.S.Y. receives the most citations per year. Tsai C.C. and Passig D. are seen working in the early 2000s. The number of writers working after 2010 appears to have grown. Tsai C.C., Hwang G., Makransky G., Cheng K.H., and Yilmaz R.M.'s research stands out in 2022 when this study was completed. Karakuş et al. (2019) found Hwang G.J. as the most prolific author and Tsai C.C. as the most influential author in the area. Wu H. K. was the most cited author also according to Karakuş et al. (2019).

Taiwan is home to the two universities with the most publications. 27 percent of the publications made by the top 20 universities were produced by the National Taiwan Normal University and National Taiwan University of Science and Technology. Karakus et al. (2019) found the National Taiwan University of Science and Technology as the most influential institution. Again, this study sees the National Taiwan Normal University as the second most influential institution. The USA has the most publications, co-authored publications, single-national publications, and cited articles overall. Abbate et al. in 2022, found the USA as the country with the highest number of publications in their general bibliometric studies on the metaverse. China is the nation with the greatest number of publications from other countries. Denmark is regarded as being at the top in the field of average citations per article.

Wu's work, "Current Status, Opportunities, and Challenges of Augmented Reality in Education," appeared in Computer & Education in 2013 and has since received the most citations worldwide. This article receives the most local citations. Six articles received no local citations. The post by Makransky entitled "Adding Immersive Virtual Reality to a Science Lab Simulation Causes Greater Presence but Less Learning" from 2019 has received the most local citations. When the yearly average number of citations is studied, the average number of citations per article is shown to be the greatest in 1995. The average number of citations is observed to be high in 2005, 2015, and 2019.

The terms "augmented reality", "virtual reality" and "second life" is sub-applications of the Metaverse environment, and are often used keywords. Over time, we can observe that prior research on “second life”, “virtual worlds” and “virtual environments” were gradually superseded by studies on “augmented reality”, “virtual reality”, “immersive virtual reality”, and “VR”. Over time, the phrase "metaverse" may become one of these tendencies. The papers in this research were subjected to cluster analysis. All clusters appear to involve “virtual reality”. Additionally, “augmented reality” was included in three clusters. Examining the measured network analysis of the authors reveals that they are clustered into five separate groups.

Conclusion

The aim of this study is to compile a bibliometric map of research on the application of the metaverse in learning. We evaluated trends in the field of metaverse research on education using the bibliometric mapping approach from a global perspective by revealing the author, publication, keyword, journal, country, and citation aspects. The majority of the study's findings were disseminated in Computers & Education. According to the findings, Hwang G.J. is the most pertinent author. The most pertinent universities are National Taiwan Normal University and National Taiwan University of Science and Technology. The USA leads the world in terms of the total number of publications, co-authored publications, single-national publications, and cited articles.

China has the highest number of publications from other countries. Denmark is rated as having the highest average number of citations per publication. The terms "augmented reality," "virtual reality," and "second life" are Metaverse sub-applications that are often used keywords. Prior research on "second life," "virtual worlds," and "virtual environments" has increasingly been supplanted by studies on "augmented reality," "virtual reality," "immersive virtual reality," and "VR." The word "metaverse" may develop one of these tendencies over time. Cluster analysis was performed on the publications in this study. Virtual reality appears to be present in all clusters. "Augmented reality" was also included in three clusters. The authors' measured network analysis suggests that they are divided into five distinct categories. Although studies on the terms "2nd life," "virtual reality," "augmented reality," and "virtual world," which are various applications of the "metaverse," have been conducted frequently, examining these studies with bibliometric analysis within the "metaverse" will aid other researchers while they work in the field.

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Author Information

Nurullah Tas

https://orcid.org/0000-0002-8312-8733

Atatürk University

Erzurum

Turkey

Contact e-mail: *nurullahtas2010@gmail.com*

Yusuf İslam Bolat

https://orcid.org/0000-0002-6120-3157

Kahramanmaraş İstiklal University

Kahramanmaraş

Turkey