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Bibliometric Mapping of Metaverse in Education

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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time, we can observe that prior research on "second life", "virtual worlds" and "virtual environments" were gradually superseded by studies on "augmented reality", "virtual reality", "immersive virtual reality", and "VR".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.

Keywords
Metaverse
Virtual reality
Augmented reality
Virtual worlds

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 (Diaz, 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 (Rospigiosi, 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.

| 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.

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                     | 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                        | 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).
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.

| 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     |
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.

| 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

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 |
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).

| 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, Tech Trends | 10.1007/s11528-012-0559-3 | 295 | 75 | 25.42 |

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

*GC= Global Cite, *LC=Local Cite

### 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.

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.

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.

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, centrality 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 Learning Environments            | 79.4    | 1     | 51    | 0.71       | 3.06   |
| Learning Teaching/Learning strategies        | 68.6    |       |       |            |        |
| 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 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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