THE BIBLIOMETRIC ANALYSIS OF THE AUGMENTED REALITY RESEARCH CARRIED OUT WITH THE EXPERIMENTAL METHOD PUBLISHED IN SCOPUS BETWEEN 2012-2022

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ABSTRACT

This study aims to make a bibliometric analysis of the augmented reality articles carried out with the experimental method between 2012 and 2022 in the Scopus database. To realize the aim of the research, 255 articles published between 2012-2022 were reached. The bibliometric data of 255 articles from the Scopus database were analyzed using VOS viewer 1.6.18 software and visualized with the Tableau software. According to the research findings, 255 articles were produced by researchers from 49 different countries. According to co-authorship networks, six different clusters were formed. National Taiwan University of Science and Technology is the leading institution in AR research with the experimental method. The 255 articles reviewed were published in 159 different journals. Interactive Learning Environments journal ranks first with 13 publications by far, while Computers and Education journal stands out with 878 citations in terms of the number of citations. When the keywords used in the articles were examined, it was seen that the concepts of virtual reality, mobile learning, motivation, and cognitive load came to the fore. The results obtained within the scope of the research were shared by discussing with other study findings obtained from the literature.

Keywords: Augmented reality, trends, bibliometric analysis, experimental study.

INTRODUCTION

Constant change and development in the fields of technology, economy, education, and sociology force the structure of human and society to change and transform. Especially the developments in the field of technology affect other fields immediately and strengthen each other. One of the innovative and remarkable technological developments today is augmented reality (Altinpulluk, 2018). As stated by Czerkawski and Berti (2021), augmented reality (AR) is among the emerging innovative technologies with significant potential for educators and students in the field of education. When the conceptual definitions made in the literature about AR technology are examined, it is seen that there are definitions that deal with this concept from different angles.

AR is a technology that provides interactive experiences by enriching analog, physical or real-world environments with virtual elements rather than a purely digital, virtual, or artificial environment as in virtual reality (Hollerer and Feiner 2004). Yuen, Yaoyuneyong, and Johnson (2011) developed this definition and

defined it as a technology in which users experience activities in the real-world environment, where they can interact with digital contents and applications developed via computer depending on a certain location. According to Richey (2018), it completes the real world with digital information through a visual interface.

AR technologies have become a usable and accessible technology in the field of education in parallel with the widespread use of mobile technologies (Sommerauer and Muller 2014). There are three types of AR technologies: markerless, marker-based, and location-based. Markerless AR uses features to track physical objects in the real environment that do not require markers. Marker-based AR technology uses a marker as a trigger. Location-based AR technology uses and observes computer-generated information on their mobile devices, based on their location determined by GPS (global positioning system) or WiFi-based positioning systems, and allows users to move around in the real environment (Wojciechowski & Celary, 2013).

When the research in the literature is examined, there are research findings that the use of AR technologies in the field of education is effective in increasing students' academic achievement (Akin, 2022; Akkus, 2021; Aslan, 2021; Eldokhny & Drwish, 2021; Gokce, 2022; Guler, 2020; Kaliyaperumal, Abd Wahab, Sagayam, Ambar, et al. Poad, 2020; Karadavut, 2021; Onur, 2021; Father Alagoz, 2020), skill development (Avci, 2022; Czerkawski and Berti, 2021; Eldokhny and Drwish, 2021), motivation boost (Akkus, 2021; Ciloglu, 2022; Onur, 2021), and self-efficacy (Ciloglu, 2022).

This research was carried out based on the need to determine the trends of experimental AR research and to provide scientific data about leading countries, institutions, journals, and authors. Before starting the research, it was examined whether there was a study evaluating the studies conducted within the scope of AR with content analysis, descriptive analysis, systematic review, extended literature review, meta-analysis, or meta-synthesis technique. In Table 1, information about the years of analysis of these studies, their titles, authors of the studies, the purpose of the studies, the databases used, and the number of analyzed publications are presented.

Table 1. Reviewing Studies on AR

Analyzed years	Title	Writer(s)	Purpose of the research & analysis dimensions	Databases	Number of analyzed publications
2007-2019	Research trends on the use of augmented reality technology in teaching english as a foreign language	Aysegul Takkac Tulgar, Rabia Meryem Yilmaz, Fatma Burcu Topu (2022)	The purpose of this study is to identify research trends in studies on AR in teaching English as a foreign language. Bibliometric mapping and content analysis were used to achieve this goal. The selected articles were discussed according to the dimensions of trend subjects, leading authors and journals, examined variables, methodologies, data collection tools, sampling methods and data analysis	Web of Science	49 articles
2015-2019	Learning strategies using augmented reality technology in education: Meta-analysis	Mohd Fadzil Abdul Hanid, Mohd. Nihra Haruzuan Mohamad Said, Noraffandy Yahaya (2020)	The purpose of this study is to identify most used learning strategies to encourage the integration of AR in different education levels. The selected articles were discussed according to the dimensions of learning strategies and levels of education (primary, secondary, or tertiary).	Web of Science, Scopus, Science Direct, Taylor Francis, Springer	17 articles

2006-2016	Determining the trends of using augmented reality in education between 2006-2016	Hakan Altinpulluk (2019)	The purpose of this study is to identify research trends in the use of augmented reality in education by examining the articles published within the scope of augmented reality in 8 educational technology journals within the scope of the Social Science Citation Index (SSCI). The selected articles were discussed according to the dimensions of years, methods, data collection tools, education field, educational advantages, the type of applications used, technologies, assets used, physical environments.	Web of Science	58 articles
2015-2016	M-learning and augmented reality: A review of the scientific literature on the WoS Repository	Javier Fombona, Maria-Angeles Pascual-Sevillano, MariCarmen Gonzalez-Videgaray (2017)	The purpose of this study is to visualize the results of bibliometric analysis on m-learning and AR. The selected articles were discussed according to the dimensions of conceptualization of the phenomenon, development of new methodologies, motivation, spatial delocalization, and implementation in subject-matter areas	Web of Science	452 articles 500 presentations 12 reviews 18 books 12 summaries 62 others
2012-2016	The use of augmented reality in formal education: A scoping review	Fatih Saltan, Omer Arslan (2017)	The purpose of this study is to provide a comprehensive overview of research on AR technology in the context of formal education. The selected articles were discussed according to the dimensions of technology (being used in AR), pedagogical approach (being integrated with AR), affordances of AR applications, educational outcomes (arising from the use of AR), limitations (regarding the use of AR).	ERIC	23 articles
2007-2015	Advantages and challenges associated with augmented reality for education: A systematic review of the literature	Murat Akcayir, Gokce Akcayir (2017)	The purpose of this study is to present a systematic review of the literature on AR used in educational settings. The selected articles were discussed according to the dimensions of years, learner types, AR technologies used for educational purposes, advantages and challenges of AR in educational settings.	Web of Science	68 articles

2003-2013	Augmented reality trends in education: A systematic review of research and applications	Jorge Bacca, Silvia Baldiris, Ramon Fabregat, Sabine Graf (2014)	The aim of this study is to perform a systematic review of the literature on AR use in educational settings and to discuss trends, the vision towards the future and opportunities for further research in AR in educational settings. The selected articles were discussed according to the dimensions of the usage AR in the education field, the purposes of using the AR in education, advantages, limitations and effectiveness in education, types of AR, research sample, research method, time dimension, data collection method	Social Science Citation Index (SSCI) Science Citation Index (SCI)	32 articles
2003-2012	The application of augmented reality in online education: A review of studies published in selected journals from 2003 to 2012	Chia-Wen Tsai, Pei-Di Shen, Ya-Ting Fan (2014)	The purpose of this study is to review AR studies published in influential international journals between 2003 and 2012. The selected articles were discussed according to the dimensions of sample groups, subject domains, research methods.	Social Science Citation Index (SSCI), Science Citation Index Expanded (SCI-EXPANDED) ve Arts & Humanities Citation Index (A&HCI)	19 articles
2004-2011	Affordances of Augmented Reality in Science Learning: Suggestions for Future Research	Kun-Hung Cheng, Chin-Chung Tsai (2014)	The purpose of this study is to identify trends and focuses in current research on AR-related science learning (e.g., astronomy, chemistry, biology, or engineering) The selected articles were discussed according to the dimensions of the technical features, focus topics, participants, and affordances in science learning.	Web of Science, Scopus	12 articles

In addition to some common findings analyzed in the studies listed in Table 1, different findings were also included in the analysis within the scope of this study. In this sense, unlike the studies mentioned in Table 1, this study has dimensions that will be examined for the first time. In addition, unlike other studies, the findings and results obtained from this study are important in terms of being a pioneering finding to identify the leading countries, institutions, journals, and authors in experimental AR research and to determine the trend of experimental AR research. It is thought that this study, in which the bibliometric data obtained from the articles carried out with the experimental method within the scope of AR is evaluated by analysis, will also shed light on future research on the subject.

The purpose of this research was to review and visualize the AR journal articles carried out with the experimental method from the Scopus database. To identify trends in the field, the following research questions were addressed:

1. In AR research which is carried out with the experimental method
   a. What is the distribution by years?
   b. What is the distribution of leading countries and institutions?
   c. What are the leading journals and authors?

d. What is the co-authorship network map like?

e. What is the bibliometric keyword analysis like?

f. What is the co-citation analysis map like?

METHOD

Determination of Studies

Certain criteria were used in the selection of the studies that were described, analyzed, and evaluated within the scope of this research. These criteria are divided into three basic categories: historical, thematic, and place of publication. The first basic criterion category for the determination of the studies examined within the scope of this research is the dates of the research. As a historical criterion, the criterion of being published in the last 10 years was used. Since the research aims to analyze the AR research carried out with the experimental method, the keywords experimental, effect, and augmented reality were used when searching the database in the second criterion category.

(TITLE-ABS-KEY("augmented reality") AND TITLE-ABS-KEY(experimental) AND TITLE-ABS-KEY(effect)) AND PUBYEAR > 2011 AND (LIMIT-TO (DOCTYPE,"ar"))

In the third criterion category, a selection was made among the articles obtained from the results of the search made in the SCOPUS database.

Data Analysis

As a result of the search performed on the Scopus database on 29 May 2022, the bibliometric data of 255 articles were exported as CSV files. Bibliometric data of the articles are the author(s), article titles, journal titles, number of citations, links, institutions the authors are affiliated with, countries, and author keywords. In this study, VOSviewer software was used to determine the most frequently used keywords in experimental studies carried out within the scope of AR and to visualize the results. In addition, a network map of co-authors and co-occurrences was created using the full count method. VOSviewer 1.6.18 was used to visualize similarities in journal articles. VOSviewer is a software for creating and visualizing bibliometric networks. The collected data and the analysis process of the data were examined by two different researchers.

Limitations of the Research

This research has some limitations. The fact that the research was carried out only with bibliometric software can be considered a limitation. The future validation of the study can be ensured by examining and analyzing the articles one by one. The studies included in the bibliometric data analysis within the scope of this study are limited to 255 AR articles published in the SCOPUS database between 2012 and 2022. The search in the Scopus database was carried out on 29 May 2022. Articles published after this date in 2022 were not examined within the scope of this research. In this study, leading countries, institutions, journals and authors in AR research with the experimental method were analyzed.

FINDINGS

The findings obtained from the bibliometric data analysis of the publications reached through a systematic literature review are presented in the relevant headings to answer the research questions.

The Distribution of the Articles by Years

The distribution of the articles by years is shown in Figure 1.

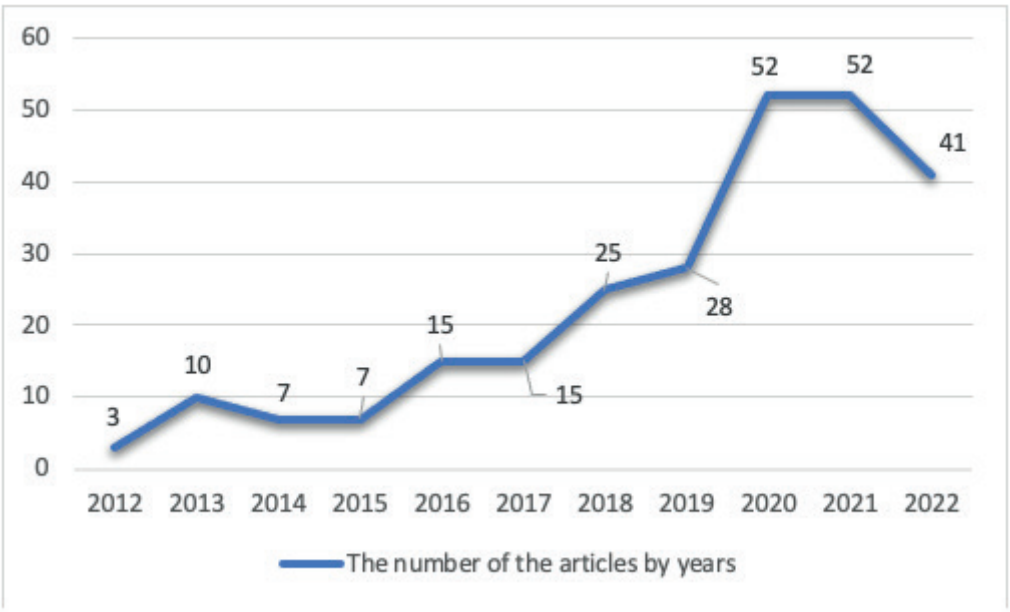

Figure 1. The number of the articles by years

When Figure 1 is examined, it is seen that the number of AR-related publications conducted with the experimental method from 2012 to 2022 has increased over the years. Since 2022 has not been completed yet, the number of articles published in 2022 seems low. However, despite the completion of half of 2022, it can be said that the number of published articles may exceed the number of articles published in 2021 at the end of the year.

Leading Countries and Institutions

To determine which countries the analyzed articles were addressed to, country data were downloaded from the Scopus database and visualized as bubble graphs in the Tableau data visualization program. Figure 2 shows the distribution of the published articles by country.

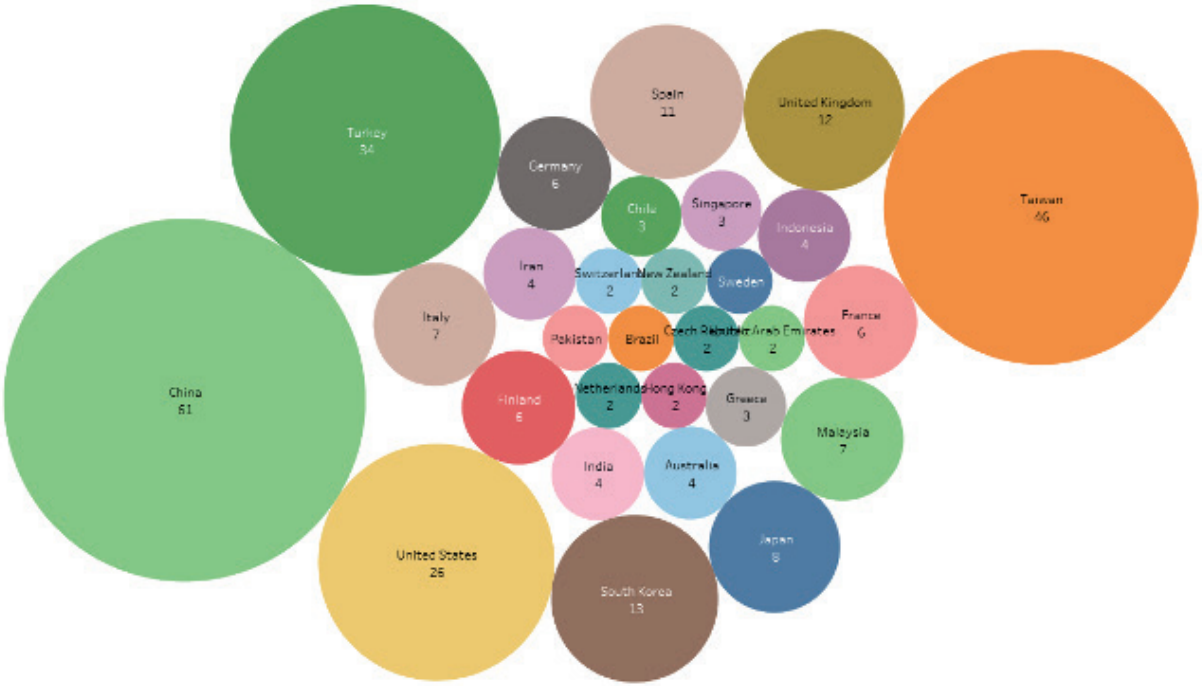

Figure 2. The Bubble Graph of the Distribution of the Articles by Country

Figure 2 includes 29 countries with at least two articles published. When the distribution of the experimental AR articles by country is analyzed, China stands out with 61 publications. Then, Taiwan (46) and Turkiye (34) are among the countries whose researchers publish more than 30 publications.255 articles were produced by researchers from 49 different countries.

The co-authorship network map by country is given in Figure 3. In the creation of the map, the analysis type was co-authorship, and the analysis unit was countries. The minimum number of documents and citations of a country is 2 (two). 27 out of 49 countries meet the threshold.

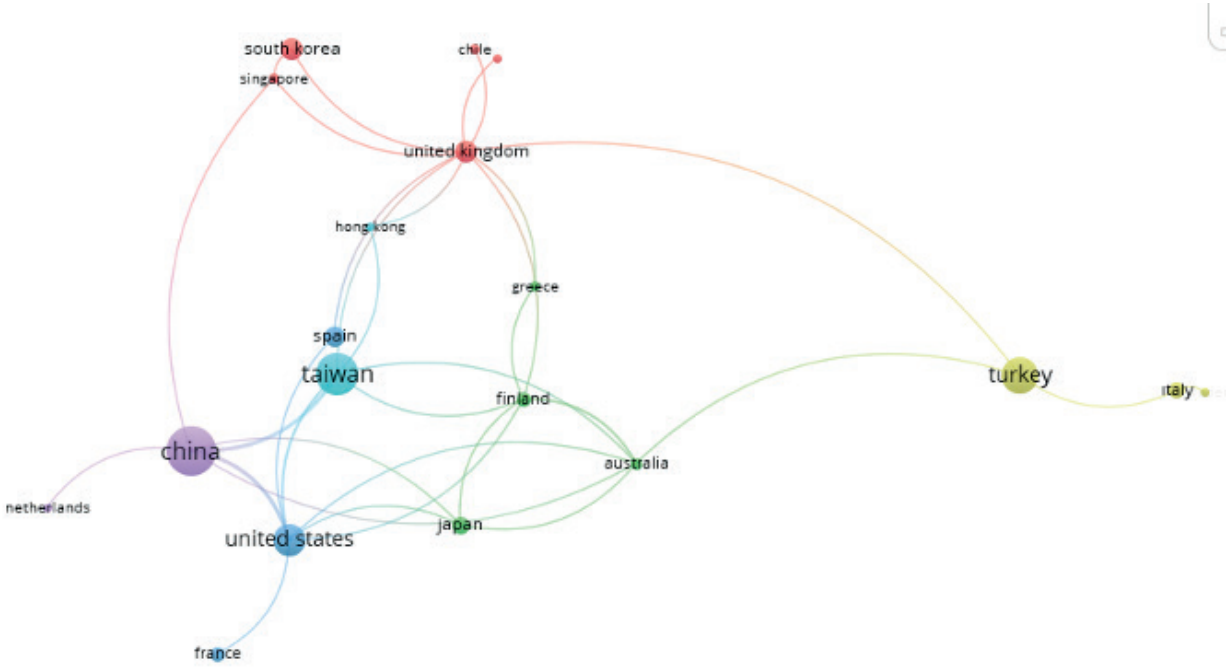

Figure 3. Co-authoring network map by the leading countries

The size of each node in the network is proportional to the total number of documents. The thickness of the connection between the nodes is proportional to the number of co-authorships. As seen in the network, 6 clusters were formed. The leading countries of these clusters are China (NDocuments=62, NCitations=380), Taiwan (ND=46, NC=743), Turkiye (ND=34, NC=881), USA. (ND=26, NC=528), Australia (ND=4, NC=73), England (ND=12, NC=242). China, the USA, Taiwan, and England acted as a connector in the network.

The institutions leading the AR research carried out with the experimental method are shown in Figure 4. These institutions are the National Taiwan University of Science and Technology (ND=9), National Taiwan Normal University (ND=9), Gazi University (ND=6), Universiti Teknologi Malaysia (ND=5), Ataturk University (ND=5), National Cheng Kung University (ND=4), Soochow University (ND=4).

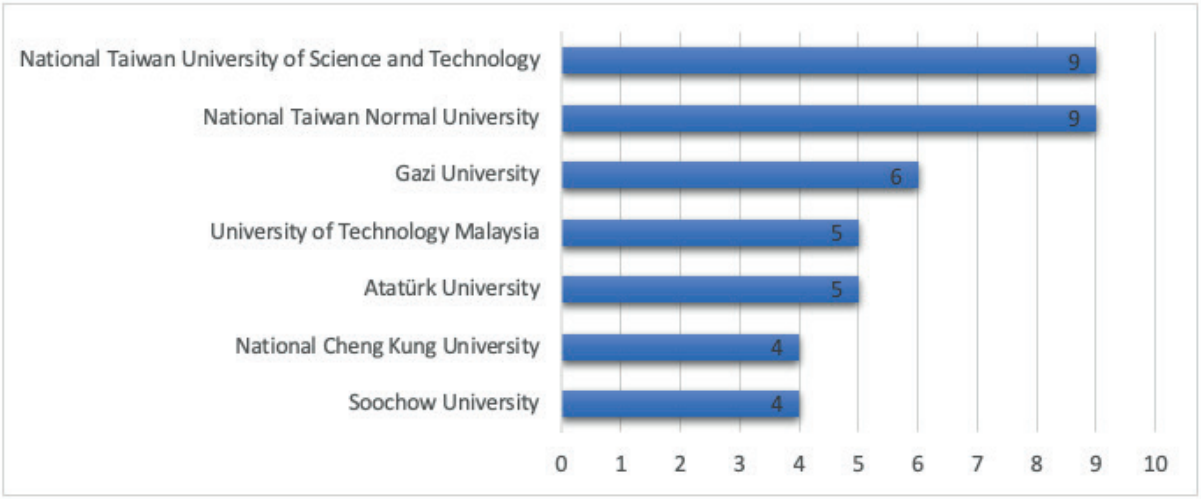

Figure 4. Leading Institutions

In order to identify the leading institutions, the VOSViewer network map created from bibliometric data was also created. Figure 5 shows the network map of the authors according to their institutions. In the creation of the network map, the type of analysis was co-authoring and the analysis unit was institutions. The minimum number of documents for an institution is 4. 7 out of 382 institutions meet the thresholds.

Figure 5. Co-authorship network map of leading institutions

In Figure 5, 6 different clusters seen in different colors were determined. In the clusters, there are prominent keywords such as the number of documents (Number of documents= ND), the number of citations (NC), and the total link strength (number of total links strength= NTLS). It was determined that only 7 of 382 institutions had co-authorship connections. Institutions leading the experimental AR research are included in the network map according to the authors' institutions and are respectively listed according to the total number of documents;, National Taiwan University of Science and Technology (ND=9, NC=424, NTLS=2) and National Taiwan Normal University (ND=9, NC=334, NTLS=2) are in the red cluster, Gazi University is in the blue cluster (ND=6, NC=335, NTLS=0), Ataturk University is in the green cluster (ND=5, NC=308, NTLS=0), Universiti Teknologi Malaysia (ND=5, NC=52, NTLS=0) is in the cyan cluster, National Cheng Kung University (ND=4, NC=63, NTLS=0) isin the yellow cluster and Soochow University is in the purple cluster (ND=4, NC=14, NTLS=0).

Leading Journals and Authors

The 255 articles reviewed were published in 159 different journals. In the ranking of 159 journals according to the total number of publications of the journals, it is seen that 123 journals made only 1 publication, and 132 articles were distributed among 36 journals. In this distribution, it has been determined that 19 journals have 2 publications, 4 journals have 3 publications, 3 journals have 4 publications, 4 journals have 5 publications, 3 journals have 6 publications, 1 journal has 7 publications, 1 journal has 9 publications and 1 journal has 13 publications. The order of the 10 journals with 5 or more publications according to the number of publications is given in Table 2 below.

Table 2. Top 10 journals according to the number of publications and citations

Journals	Citations, n	Articles, n
Interactive Learning Environments	304	13
Education and Information Technologies	45	9
IEEE Access	20	7
Computers and Education	878	6
Computers in Human Behavior	394	6
Journal of Computer Assisted Learning	77	6
IEEE Transactions on Visualization and Computer Graphics	64	5
Optics Express	30	5
British Journal of Educational Technology	29	5
Sustainability Switzerland	21	5

As can be seen in Table 2, among the journals with 5 or more publications, Interactive Learning Environments journal ranked first with 13 publications, Education and Information Technologies journal ranked second with 9 publications, and IEEE Access journal ranked third with 7 publications. Computers and Education, Computers in Human Behavior, and Journal of Computer Assisted Learning are journals with 6 publications. 4 journals with 5 publications are IEEE Transactions on Visualization and Computer Graphics, Optics Express, British Journal of Educational Technology, and Sustainability Switzerland. In terms of the number of citations, Computers and Education with 878 citations, Computers in Human Behavior with 394 citations, and Interactive Learning Environments with 304 citations stood out.

In this study, 255 articles were published by 828 authors. Figure 6 shows the co-authorship network map of the articles. In the creation of the network map, the analysis type was co-authoring, and the analysis unit was the authors. The minimum number of documents and citations for an author is 2. Out of 828 authors, 77 meet the thresholds.

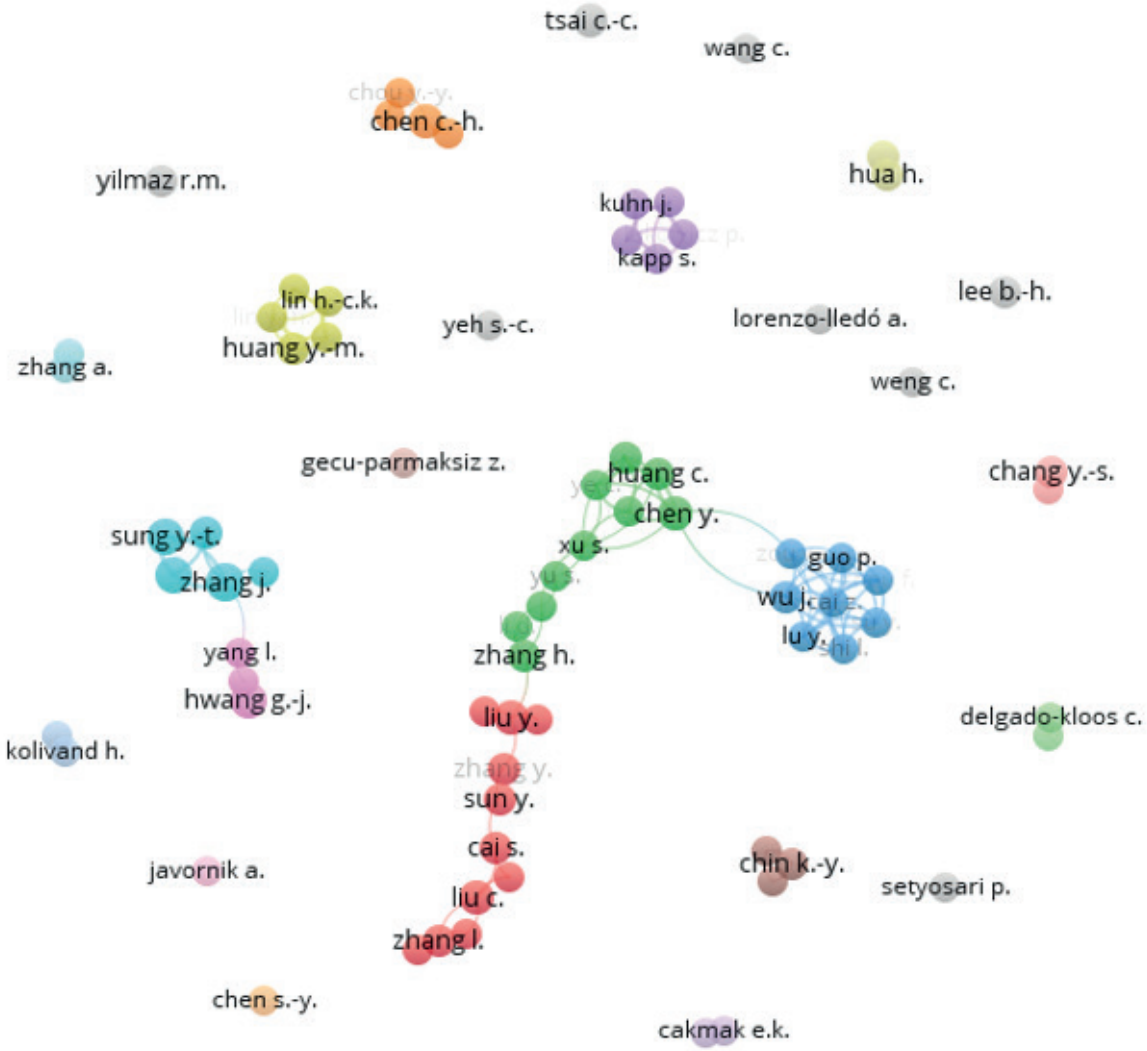

Figure 6. Co-authorship network map of 77 authors

As seen in the figure, many co-authorship clusters were formed among the authors. The 9 featured authors according to the total number of documents and the number of citations are given in Table 3 below.

Table 3. Top 9 authors by the number of publications and citations

Author	Institution and Country	Publications, n	Citations, n
Delgado-Kloos, Carlos	Universidad Carlos III de Madrid, Spain	2	330
Maria-Blanca, Ibanez	Universidad Carlos III de Madrid, Spain	2	330
Chang, Kuo-En	National Taiwan Normal University, Taiwan	5	262
Sung, Yao-Ting	National Taiwan Normal University, Taiwan	5	262
Hwang, GwoJen	National Taiwan University of Science and Technology, Taiwan	5	166
Yilmaz, Rabia Meryem	Ataturk University, Turkiye	3	152
Javornik, Ana	University of Bristol, United Kingdom	2	133
Cai, Su	Beijing Normal University, China	3	132
Zhang, Jia	National Taiwan Normal University, Taiwan	7	124

Looking at Table 3, Zhang J stood out with 7 articles, while Delgado-Kloos and Ibanez stood out with 330 citations. Of the 77 authors who meet the minimum 2 documents and 2 citation thresholds, 26 have an affiliate network. Looking at the featured authors in the co-authorship cluster, it seems that there is a connection between the co-authorship clusters between Chen, Y, and Wu, J.

As can be seen in Figure 7, in the co-authorship network map of 29 linked authors, 5 clusters were formed in the network. It is seen that Chen Y and Wu J stand out in terms of centrality and inter-cluster linking. When the connections between the co-authorship clusters are examined, it is seen that there is a connection between Cai S and Sung, Y, between Liu, Y and Zhang, H, between Xu, S and Chen, Y, and between Chen, Y and Wu, J.

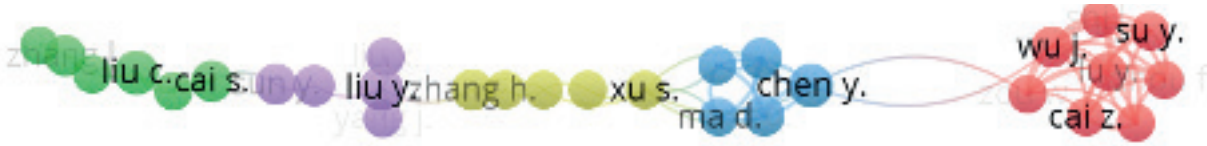

Figure 7. Co-authorship network map of 29 affiliated authors

Trends in AR Articles with the Experimental Method

The co-occurrence analyzes of the author keywords were carried out using the full count method. Figure 8 shows a network visualization of the author's keyword map. In the creation of the network map, the analysis type was "co-occurrance" and the analysis unit was "author". The minimum repeat count of a keyword is 4. Of the 784 keywords, 14 meet the threshold.

Figure 8 shows the co-authored network map of the 14 keywords that meet the threshold.

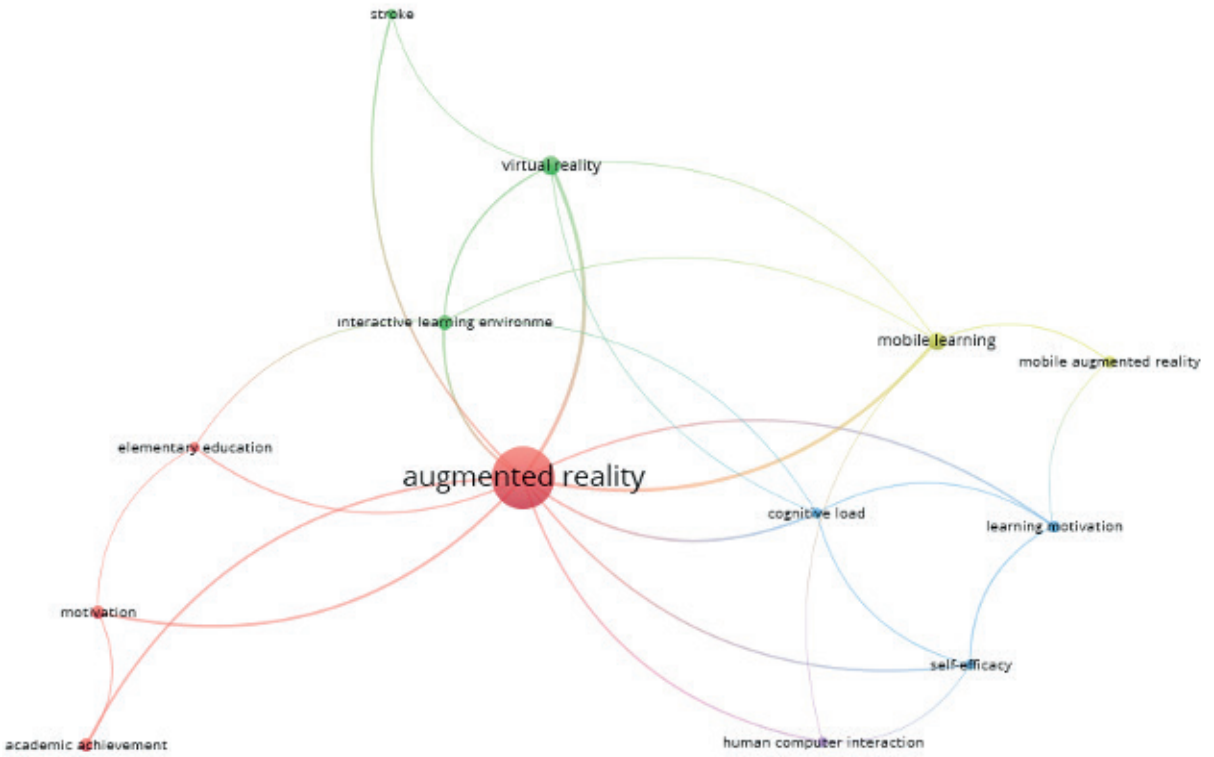

Figure 8. Co-occurrence map of authors' keywords

"Augmented reality", "Augmented reality (ar)" and "Mobile augmented reality" keywords were extracted from detailed keywords to identify trends in AR studies carried out with the experimental method. Figure 9 contains 11 keywords.

Figure 9. Co-occurrence map of authors' keywords

In Figure 9, 4 different clusters seen in different colors were determined. In clusters, some keywords stand out according to the number of occurrences and the number of total link strength (NTLS). "Virtual reality" (Number of Occurrence=14, NTotal Link Strength=17) in the blue cluster and "mobile learning" (NO=13, NTLS=15) in the yellow cluster were the most important keywords in terms of their centrality, overall weight, density, and degree of overlap with the other topics. In other keywords, "motivation" (NO=7, NTLS=9) is given in the red cluster and "cognitive load" (NO=5, NTLS=11) is given in the green cluster.

In Figure 10, an overlay visualization map of the keywords according to years was created to reveal the change of AR studies carried out with the experimental method according to time.

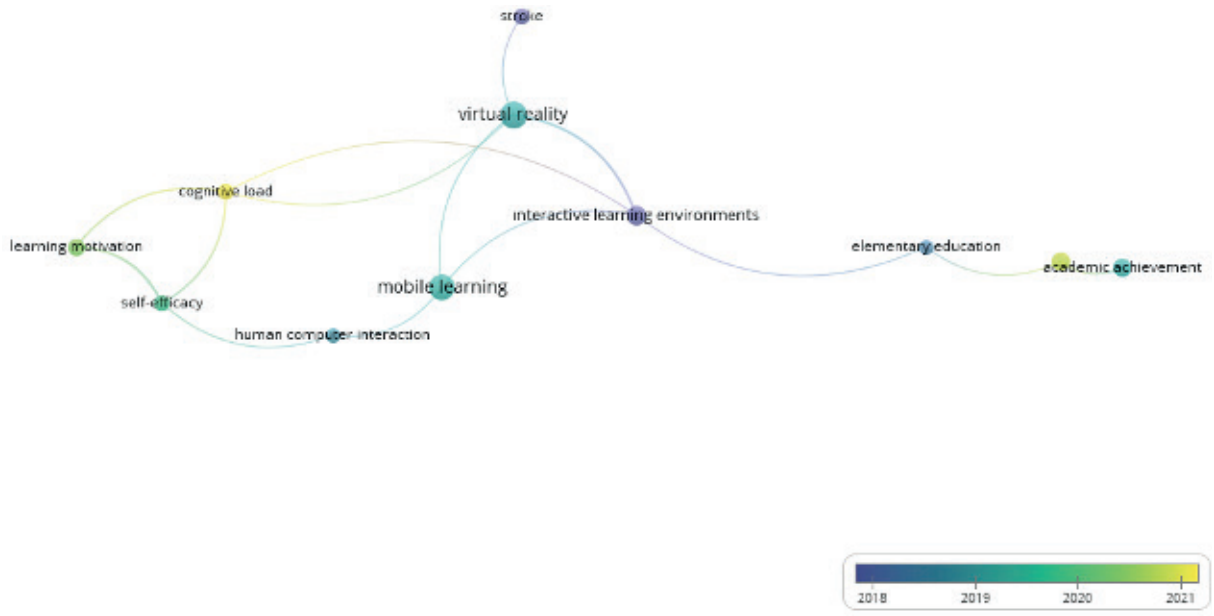

Figure 10. Keyword co-occurrence map of authors by year

According to the historical change, while the concept of "interactive learning environments" came to the fore in 2018; in 2019 the concepts of "mobile learning", "human-computer interaction", in 2020"self-efficacy", "learning motivation", "academic success", "academic success" and in current articles after 2021 the concepts of "cognitive load" and "motivation" come to the fore.

Bibliographic link analysis was performed to see a holistic network map of the articles. Figure 11 shows the visualization of the co-citation bibliometric analyzes of the articles.

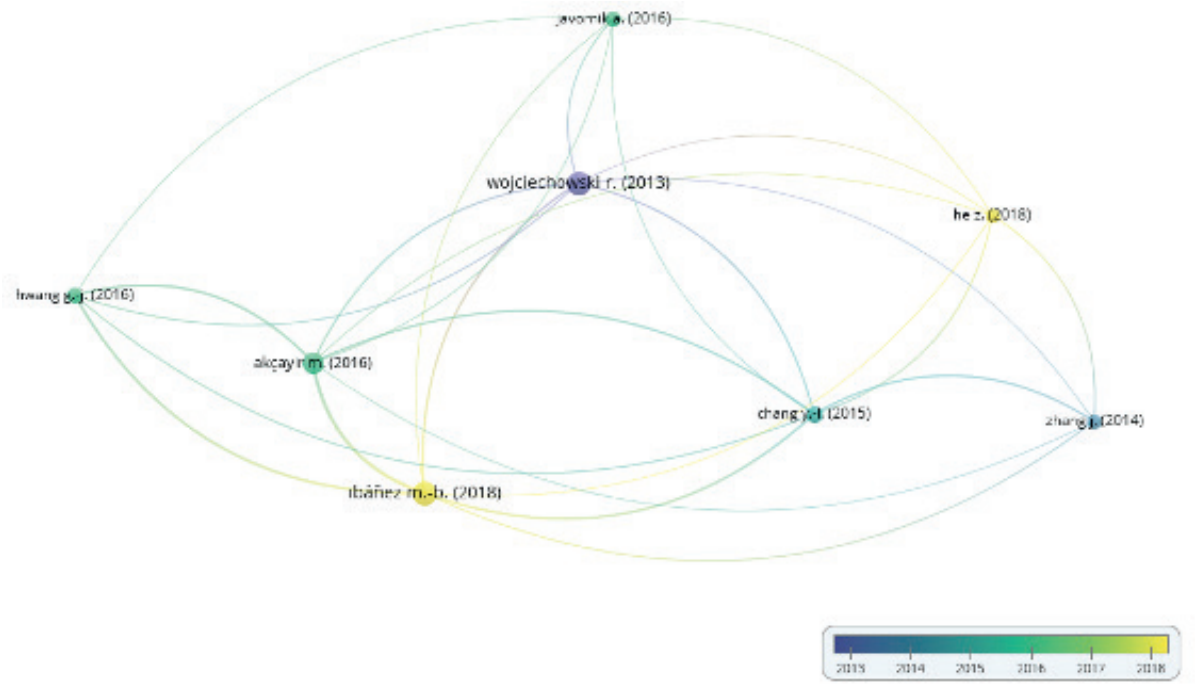

Figure 11. Bibliographic coupling analyses of articles

In the creation of the network map, the type of analysis was bibliographic coupling, the analysis unit was documents. Bibliographic coupling, like co-citation, is a similarity measure that uses citation analysis to establish a similarity relationship between documents. As expected, Figure 10 shows that older articles are more cited. Most cited articles with 100 or more citations are included in Table 4.

Table 4. Articles with 100 or more citations

Author(s)	Article Title	Year	Journal Name	Number of Citation
Wojciechowski R., Cellary W.	Evaluation of learners' attitude toward learning in ARIES augmented reality environments	2013	Computers and Education	279
Ibanez M. B., Delgado-Kloos C.	Augmented reality for STEM learning: A systematic review	2018	Computers and Education	272
Akcayir M., Akcayir G., Pektas H.M., Ocak M.A.	Augmented reality in science laboratories: The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories	2016	Computers in Human Behavior	231
Kucuk S., Kapakin S., Goktas Y.	Learning anatomy via mobile augmented reality: Effects on achievement and cognitive load	2016	Anatomical sciences education	156
Chang Y.-L., Hon H.-T., Pan C.-Y., Sung Y.-T., Chang K.-E.	Apply an augmented reality in a mobile guidance to increase sense of place for heritage places	2015	Educational Technology and Society	138
Javornik, A.	'It's an illusion, but it looks real!' Consumer affective, cognitive and behavioural responses to augmented reality applications	2016	Journal of Marketing Management	126
He Z., Wu L., Li X.R.	When art meets tech: The role of augmented reality in enhancing museum experiences and purchase intentions	2018	Tourism Management	109
Zhang J., Sung Y.-T., Hou H.-T., Chang K.-E.	The development and evaluation of an augmented reality-based armillary sphere for astronomical observation instruction	2014	Computers and Education	104

Co-citation analysis of cited references performed with full counting method. In the creation of the network map, the type of analysis was co-citation, and the unit of analysis was cited references. The minimum number of citations of a cited reference was limited to 6. Of 11347 cited references, 22 meet the threshold. Figure 12 shows the co-citation network map of 22 connected articles.

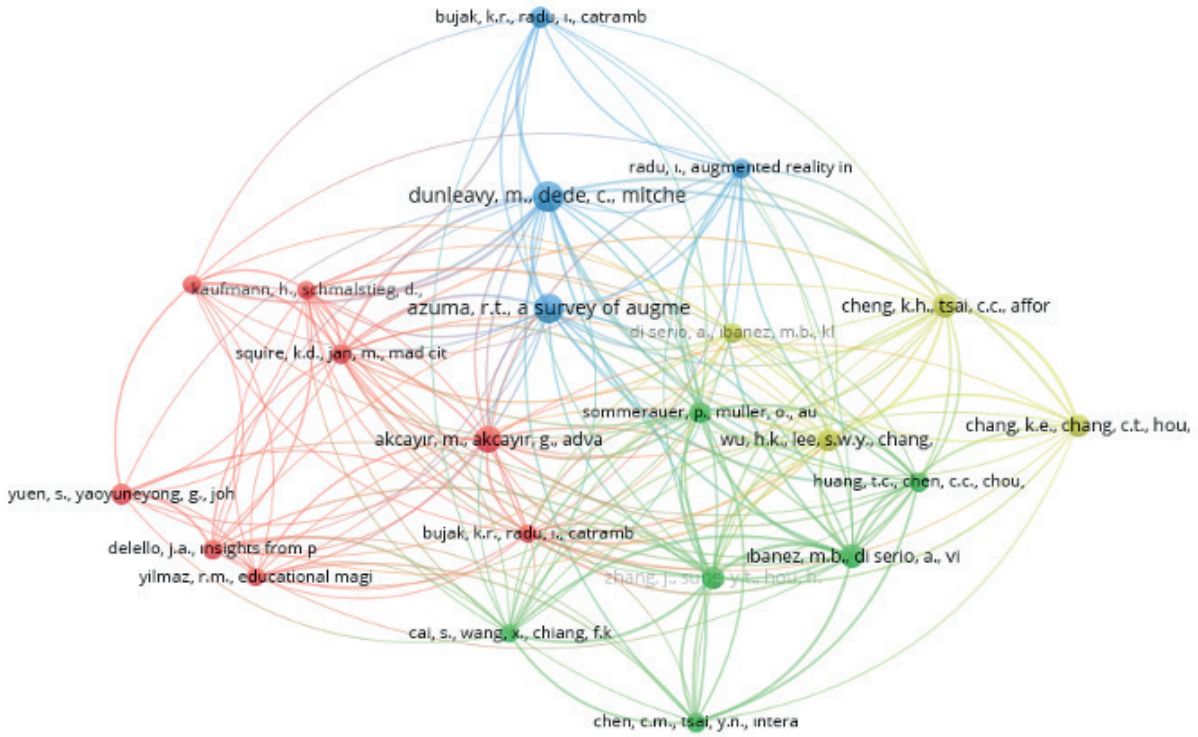

Figure 12. Co-citation analysis map of articles

The common citation analysis map includes 4 clusters. The distribution of articles into clusters is listed in Table 5.

Table 5. The distribution of articles to clusters based on co-citation

Article	Cluster	Weight <Links>	Weight <Total link strength>	Weight <Citations>
Akcayir, M., & Akcayir, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*, *20*, 1-11.	Conceptual framework of augmented reality	17	29	13
Bujak, K. R., Radu, I., Catrambone, R., MacIntyre, B., Zheng, R., & Golubski, G. (2013). A psychological perspective on augmented reality in the mathematics classroom. *Computers & Education*, *68*, 536-544.	Conceptual framework of augmented reality	19	30	6
Delello, J. A. (2014). Insights from pre-service teachers using science-based augmented reality. *Journal of computers in education*, *1*(4), 295-311.	Conceptual framework of augmented reality	15	23	7

Kaufmann, H., & Schmalstieg, D. (2002). Mathematics and geometry education with collaborative augmented reality. In *ACM SIGGRAPH 2002 conference abstracts and applications* (pp. 37-41).	Conceptual framework of augmented reality	17	30	6
Squire, K. D., & Jan, M. (2007). Mad city mystery: Developing scientific argumentation skills with a place-based augmented reality game on handheld computers. *Journal of science education and technology*, *16*(1), 5-29.	Conceptual framework of augmented reality	18	34	7
Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & education*, *62*, 41-49.	Conceptual framework of augmented reality	13	20	6
Yilmaz, R. M. (2016). Educational magic toys developed with augmented reality technology for early childhood education. *Computers in human behavior*, *54*, 240-248.	Conceptual framework of augmented reality	13	17	6
Yuen, S. C. Y., Yaoyuneyong, G., & Johnson, E. (2011). Augmented reality: An overview and five directions for AR in education. *Journal of Educational Technology Development and Exchange (JETDE)*, *4*(1), 11.	Conceptual framework of augmented reality	11	14	8
Cai, S., Wang, X., & Chiang, F. K. (2014). A case study of Augmented Reality simulation system application in a chemistry course. *Computers in human behavior*, *37*, 31-40.	Development and implementation of augmented reality application	18	30	6
Chen, C. M., & Tsai, Y. N. (2012). Interactive augmented reality system for enhancing library instruction in elementary schools. *Computers & Education*, *59*(2), 638-652.	Development and implementation of augmented reality application	14	30	7
Huang, T. C., Chen, C. C., & Chou, Y. W. (2016). Animating eco-education: To see, feel, and discover in an augmented reality-based experiential learning environment. *Computers & Education*, *96*, 72-82.	Development and implementation of augmented reality application	14	30	7
Ibanez, M. B., Di Serio, A., Villaran, D., & Kloos, C. D. (2014). Experimenting with electromagnetism using augmented reality: Impact on flow student experience and educational effectiveness. *Computers & Education*, *71*, 1-13.	Development and implementation of augmented reality application	18	54	11
Sommerauer, P., & Muller, O. (2014). Augmented reality in informal learning environments: A field experiment in a mathematics exhibition. *Computers & education*, *79*, 59-68.	Development and implementation of augmented reality application	18	42	8
Zhang, J., Sung, Y. T., Hou, H. T., & Chang, K. E. (2014). The development and evaluation of an augmented reality-based armillary sphere for astronomical observation instruction. *Computers & education*, *73*, 178-188.	Development and implementation of augmented reality application	19	44	9
Azuma, R. T. (1997). A survey of augmented reality. *Presence: teleoperators & virtual environments*, *6*(4), 355-385.	Survey of augmented reality	18	37	16
Bujak, K. R., Radu, I., Catrambone, R., MacIntyre, B., Zheng, R., & Golubski, G. (2013). A psychological perspective on augmented reality in the mathematics classroom. *Computers & Education*, *68*, 536-544.	Survey of augmented reality	11	19	8

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of science Education and Technology*, *18*(1), 7-22.	Survey of augmented reality	21	59	18
Radu, I. (2014). Augmented reality in education: a meta-review and cross-media analysis. *Personal and ubiquitous computing*, *18*(6), 1533-1543.	Survey of augmented reality	14	24	7
Chang, K. E., Chang, C. T., Hou, H. T., Sung, Y. T., Chao, H. L., & Lee, C. M. (2014). Development and behavioral pattern analysis of a mobile guide system with augmented reality for painting appreciation instruction in an art museum. *Computers & education*, *71*, 185-197.	Development augmented reality system	11	24	9
Cheng, K. H., & Tsai, C. C. (2013). Affordances of augmented reality in science learning: Suggestions for future research. *Journal of science education and technology*, *22*(4), 449-462.	Development augmented reality system	17	36	11
Di Serio, A., Ibanez, M. B., & Kloos, C. D. (2013). Impact of an augmented reality system on students' motivation for a visual art course. *Computers & Education*, *68*, 586-596.	Development augmented reality system	15	25	7
Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & education*, *62*, 41-49.	Development augmented reality system	19	45	9

The study subjects of the articles in the 4 clusters given in the table were analyzed. Cluster 1 "Conceptual framework of augmented reality" colored in red, Cluster 2 "Development and implementation of augmented reality application" colored in green, Cluster 3 "Survey of augmented reality" colored in blue, Cluster 4 colored in yellow is named as "Development augmented reality system".

CONCLUSION AND DISCUSSION

It has been determined that the number of AR-related publications conducted with the experimental method from 2012 to 2022 has generally increased over the years. 2014 was the only year in which the number of published articles decreased compared to the previous year. It was determined that the same number of articles were published in 2015, 2017, and 2021 as in the previous year. When the survey studies on AR in the literature are examined, the finding that the number of publications on AR with experimental methods has increased over the years shows similarities with the research findings obtained by Altinpulluk (2019), Icten and Bal (2017), and Turker (2021). Altinpulluk (2019) revealed that there has been a sudden increase in the number of publications in the field of AR since 2013, by examining the articles published within the scope of AR in 8 educational technology journals within the scope of the Social Science Citation Index (SSCI) between 2006-2016 and trying to determine the trends in AR use in education. He also pointed out that the interest in the use of AR applications in education has increased. Icten and Bal (2017) analyzed 34 academic studies on AR, published in 27 international and national journals between 2010 and 2016, using the content analysis method, and stated that although there were close values from 2010 to 2016, there was a slight increase over the years. Turker (2021), as a result of his research on the use of AR technology in education, in which he examined the postgraduate theses published in the field of education, stated that the number of thesis studies on AR technology from 2014 to 2019 increased.

It was stated that 255 articles published on AR, which were carried out with the experimental method, were produced by researchers from 49 different countries. When the distribution of articles by country is

examined, China has come to the fore with 61 publications. Then, Taiwan (46) and Turkiye (34) are among the countries with researchers with more than 30 publications. China, Taiwan, and Turkiye are found as the leading countries by the number of documents. Similar to this research finding, Altinpulluk (2019) stated that Taiwan is the country where the most studies were carried out within the scope of AR, and after Taiwan, research was carried out in the USA, Spain, South Korea, Turkiye, and China, respectively. Co-authorship network map of leading countries formed 6 clusters. China, Taiwan, Turkiye, the USA, Australia, and England are leading these clusters. China, the USA, Taiwan, and England acted as connectors in the network.

According to the total number of documents, the leading institutions in the published articles on the experimental AR were the National Taiwan University of Science and Technology, National Taiwan Normal University, Gazi University, Universiti Teknologi Malaysia, Ataturk University, National Cheng Kung University, Soochow University, respectively. When the survey studies on AR were examined in the literature, no other findings similar to this one was found.

It was determined that 255 articles published on AR, which were carried out with the experimental method, were published in 159 different journals. Interactive Learning Environments journal was in first place with 13 publications. In terms of the number of citations, Computers and Education with 878 citations, Computers in Human Behavior with 394 citations, and Interactive Learning Environments with 304 citations stood out. In terms of the number of publications, Icten and Bal (2017) obtained a finding similar to the finding about leading journals in AR research conducted with the experimental method. Icten and Bal (2017) found that the 34 studies they examined were published in 27 different journals, and the first three journals in which the most studies were published were IEEE Access, Computers & Education, and Procedia, respectively. In terms of the number of citations, a finding similar to the finding about the leading journals in AR research conducted with the experimental method was made by Takkac Tulgar et al. (2022). To show the research trends in the studies on AR in teaching English as a foreign language by using bibliometric mapping and content analysis, Takkac Tulgar et al. (2022) found that the Journal of Computer Assisted Learning stood out with 106 citations in terms of the number of citations, the British Journal of Educational Technology journal came second with 54 citations and Computers and Education was third with 19 citations.

In terms of the number of citations, a finding similar to the finding about leading authors in AR research conducted with the experimental method was found by Takkac Tulgar et al. (2022). Takkac Tulgar et al. (2022) found that Liu, T.Y. stood out with 106 citations among 16 authors with at least 10 citations in studies on AR in teaching as a foreign language. It was similarly seen in the research by Takkac Tulgar et al. (2022) that Ibanez, M., Hwang, G., and Cai, S., were among the most cited authors.

For the research trend of augmented reality research carried out with experimental method; authors' keywords co-occurrence, overlay visualization of authors' keywords and bibliographic coupling analyses of articles were conducted. As a result of the authors' keywords co-occurrence analysis, the prominent concepts were "Virtual reality" and "mobile learning". Those were the most important keywords in terms of their centrality, overall weight, density, and degree of overlap with the other topics.

When the survey studies on AR in the literature are examined, a finding similar to the finding that mobile learning comes to the fore was found by Ozaydin Aydogdu and Eryilmaz (2019) and Takkac Tulgar et al. (2022), a finding similar to the finding that the concept of virtual reality comes to the fore was obtained by Altinpulluk (2019) Ozaydin Aydogdu and Eryilmaz (2019) analyzed the studies on AR in higher education in Turkiye and abroad in Eric and Academic Search Complete databases with descriptive analysis method. They stated that the most used AR technology in researches conducted both in Turkiye and abroad is mobile technologies and AR applications are oriented towards the mobile field. Takkac Tulgar et al. (2022) determined that the most used keywords in studies on AR in foreign language teaching are mobile learning, Aurasma, and mobile games. Altinpulluk (2019) stated that the most used keywords in the articles published within the scope of AR are interactive learning environments and virtual reality, respectively.

When the change of keywords according to years is analyzed in the analysis, while the concept of "interactive learning environments" came to the fore in 2018, in 2019 the concepts of "mobile learning", "human-computer interaction", in 2020 "self-efficacy", "learning motivation", "academic success", and in current articles after 2021 the concepts of "cognitive load" and "motivation" come to the fore. A finding similar

to was found by Takkac Tulgar et al. (2022). Takkac Tulgar et al. (2022), in their studies on AR in foreign language teaching, found that mobile learning, gamification, and mobile games became the focus of research in 2015-2019.

Bibliographic link analysis was performed to see a holistic network map of the articles. As a result of the analysis, it was determined that older articles received more citations. It can be said that this finding is quite an expected one.

Co-citation analysis of articles revealed 4 clusters. These clusters are named "Conceptual framework of augmented reality", "Development and implementation of augmented reality application", "Survey of augmented reality" and "Development augmented reality system". When the survey studies on AR are examined in the literature, it can be stated that such an analysis has never been made.

Recommendations

Based on the findings obtained from this study, some recommendations were made. Fields such as mobile learning, human-computer interaction, and interactive learning environments, which have become trend topics, can be determined as research topics in prospective research on AR technologies to be carried out with the experimental method. At the same time, since it is seen that the keywords used in these studies focus on the concept of secondary education, it can be suggested that future experimental studies be carried out in higher education institutions.

This research focuses on leading countries, institutions, journals, and authors in experimental studies. The bibliometric data obtained from this research provides important findings to the researchers who will work experimentally with AR technologies about the researches of the authors who have the most references, the researches of the authors who have done the most research, in which countries and in which institutions these researches are studied more, in which journals the studies in this field are published the most, and which topics in these researches are discussed. Methodological variables such as research model, sample size, target population, which were not examined in this study, can be examined in future studies.

Since AR is a new technology, it has been determined that its effects on learning success, self-efficacy, performance, cognitive load, and motivation have been examined more in experimental studies. However, it was seen that there was no study on variables such as readiness, attitude, perception, and acceptance. For this reason, future research can be recommended to investigate teachers' and students' readiness, attitude, perception, and acceptance levels toward AR technologies.

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