



Bibliometric analysis of augmented reality in education and social science

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Citation: Masalimova, A. R., Erdyneeva, K. G., Kryukova, N. I., Khlusyanov, O. V., Chudnovskiy, A. D., & Dobrokhoto, D. A. (2023). Bibliometric analysis of augmented reality in education and social science. *Online Journal of Communication and Media Technologies*, 13(2), e202316. <https://doi.org/10.30935/ojcm/13018>

ARTICLE INFO

Received: 27 Dec 2022

Accepted: 28 Feb 2023

ABSTRACT

Augmented reality (AR) overlays virtual elements on real-time images. Because of its ubiquitous use on desktop computers and handheld devices, it has become a major study topic. AR provides benefits like engagement, motivation, and learning result, but drawbacks like the technology tool and application and pedagogical challenges. After 2015, global Google searches for AR increased. This study analyzed "AR" literature released after 2015. Exclusion and inclusion criteria are studies were divided into social sciences and education and published in English. Research should be published during 2015-2022. 3,823 studies were analyzed. AR publications will increase after 2020. Annual citations averaged 2.49. Computer & Education leads the top ten journals in citations. National Taiwan Normal University and Beijing Normal University have the most publications when ordered by writers' institutions. China leads global publications, whereas the US leads overall publications. China led in citations, followed by the US. Macedonia led the average number of article citations, followed by Israel. The strategic map shows the center and density of key issues. "Student learning," "AR applications," and "AR technology" are linked and vital terms. Based on the results of the bibliometric study, researchers who wish to work on AR may emphasize theme-based learning studies and AR. Researchers that are considering conducting bibliometric analysis on AR are urged to conduct research utilizing many databases.

Keywords: bibliometric analysis, augmented reality, education, social science, review

INTRODUCTION

Innovations in technology can have far-reaching effects on the educational system and prompt significant change. Augmented reality (AR) is a technology that allows interactively superimposed virtual objects on real-time images (Azuma, 1997). Over the past few years, AR has developed into a significant area of focus for research. The fact that expensive hardware and complicated equipment are no longer necessary for utilizing AR technology is among the most significant factors contributing to its widespread adoption. The technology can now be applied to desktop computers as well as portable electronic gadgets. Consequently, making use of AR technology is not nearly as challenging as it was in the past (Akçayir & Akçayir, 2017).

In contrast to virtual reality (VR), which immerses the user's senses in an artificial environment, AR allows the user to view the actual world through a virtual overlay. In AR systems, virtual items may comprise text, still photographs, video clips, sounds, 3D models, and animations. Idealistically, these virtual items will be viewed as coexisting alongside those in the actual world (Bower et al., 2014). AR is a novel strategy for enhancing the learning of three-dimensional forms as opposed to the conventional method (Saidin et al., 2015).

Like every technology included in the educational environment, AR has certain advantages as well as disadvantages. Engagement, motivation, and learning outcome are main advantages that are stated in literature. The disadvantages and challenges of AR can be classified under two headings: first, those arising from the nature of the technological tool and second, the difficulties arising from the application and pedagogical approach.

The affordances of AR make it feasible to increase the number of ways in which the user may engage with academic materials, hence increasing the likelihood that the material will be retained by the learner (Herpich et al., 2018; Kaur et al., 2020). The addition of information using AR to a real setting, such as a classroom, helps to increase both student engagement and subject comprehension (Mundy et al., 2019). Using AR devices in the classroom has been shown to boost student engagement.

Motivation may be described as an individual's capacity to begin and regulate behavior for a certain task. Students who have a strong desire to learn are more likely to put in the effort required to see a work through to its conclusion (Kaur et al., 2020). AR has the potential to provide users with a more satisfying experience by boosting learner motivation (Volioti et al., 2022). According to the findings of a considerable number of studies (Kaur et al., 2020; Khan et al., 2019; Sandoval Pérez et al., 2022; Taskiran, 2019) the use of AR has a beneficial impact on the participants' levels of motivation.

One of the ultimate purposes of using technological opportunities is to increase the learning levels of students. AR tools are utilized by a wide variety of participants, ranging from preschool pupils to post-graduate students and instructors in a variety of subjects, from literacy education to astronomy education (Sirakaya & Cakmak, 2018). AR application has provided an increase in the academic success of learners in the astronomy (Yen et al., 2013), mathematics (Estapa & Nadolny, 2015), critical thinking (Damopolii et al., 2022), English (Ebadi & Ashrafabadi, 2022), science (Abdullah et al., 2022), programming (Tsai & Lai, 2022), social sciences (Toledo-Morales & Sanchez-Garcia, 2018), and health sciences (Rodríguez-Abad et al., 2021).

The first limitations and difficulties of AR stem from the nature of the technology itself. They relate to the difficulty of the technology in and of itself, the expense involved, or the incompatibility of the many devices (Hsiao, 2013; Marín-Díaz, 2017). Design flaws that slow down the learning devices (Akçayir & Akçayir, 2017) are another issue that must be overcome. Another difficulty is the cost of the apps and the devices (Yip et al., 2019). Using smart glasses, Bogomolova et al. (2020) were able to visualize the AR educational content. They mentioned a number of issues, such as the difficulty in adjusting the glasses, the volatility of the picture that was being projected, and the requirement to keep the head motionless.

The use of different instructional strategies and activities is still another obstacle. According to Matcha and Rambli (2013), the use of technology in education leads to a reduction in the amount of communication and interaction that occurs between and among students. The absence of teacher training to generate materials connected to AR (Marín-Díaz, 2017; Toledo-Morales & Sanchez-Garcia, 2018). The use of head-mounted displays has a detrimental impact on one's ability to interact with other people (Billinghurst et al., 2003). Due

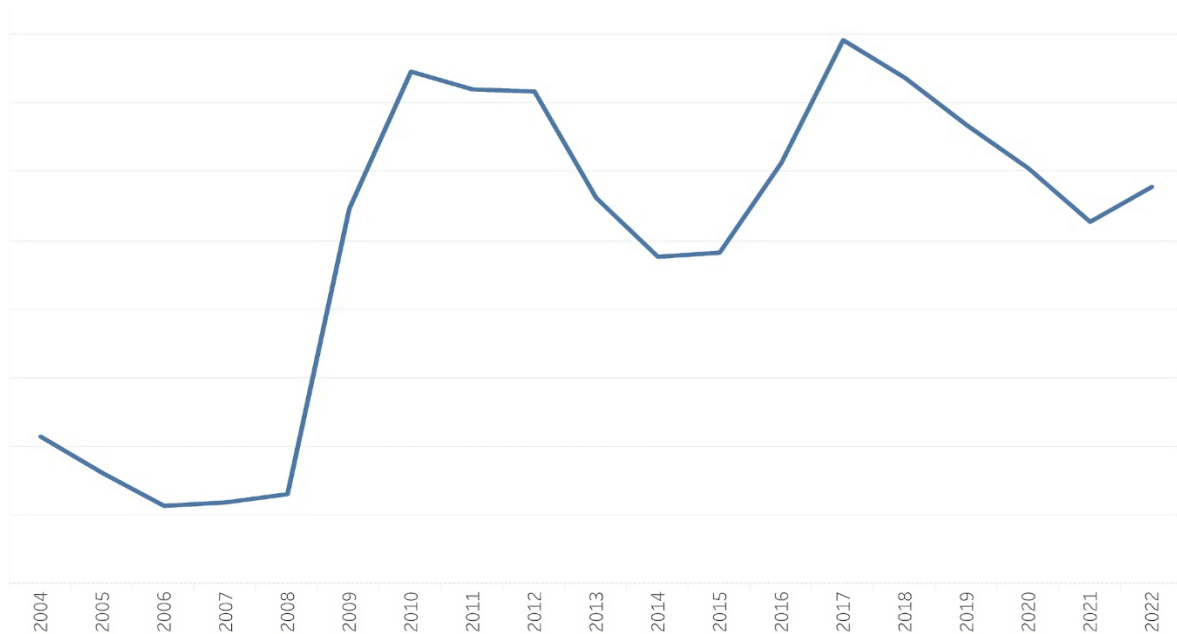


Figure 1. Google search trend for AR (Source: Authors' own elaboration)

to the fact that this endeavor requires a lot of time (Laine et al., 2016). Another significant obstacle is the requirement that learners acquire knowledge of AR (Cai et al., 2017; Huang et al., 2016).

With the advancement of computer technology and methods, bibliometric analysis has become increasingly prevalent. Bibliometrics is the measuring of a clearly defined body of study including physical units of publications, bibliographic citations, and surrogates (Broadus, 1987). Using bibliographic analysis, research items in a scientific field can be categorized according to their bibliographic information, such as citations, keywords, themes, institutions, nations, authors, sources, and titles. Using more complex bibliographic analysis techniques, a researcher may generate bibliographic maps from the same data, display and explore these maps, evaluate bibliometric networks, create bibliographic coupling, and assess the strength of the bibliographic coupling relationships (Karakus et al., 2019).

According to the statistics of google searches conducted around the world, an increase in searches related to AR has been observed after 2015 (Figure 1). This study aimed to make a bibliographic analysis of the publication related to "AR" published after 2015. These research questions were addressed:

1. What is the trend in the publication of AR?
2. What are the most authoritative sources on AR?
3. What are the most influential AR publications?
4. Who are the leading researchers in AR gamification?
5. Which nations and institutes have contributed to AR research?
6. What are AR's research front and intellectual foundation?
7. What cooperation arrangements do the authors employ in the field of AR?

METHOD

This research is qualitative research with descriptive analysis techniques and literature studies that are equipped with bibliometric analysis. The purpose of the study is to describe existing phenomena, both those that are happening currently and those that have happened in the past, as well as various topics that are related to AR. This bibliometric study has a comprehensive scope, investigating the existing circumstances and trends associated with AR research in the years 2015 to 2022 according to the specifications set for the research processes. This search was carried out in the year 2023, and the Scopus database was utilized as the major resource for obtaining bibliographic information. Logical operators were utilized to attain the goal of conducting a more comprehensive investigation. The following search term is used in Scopus:

Table 1. Descriptive information on dataset

Description	Results
Main information about data	
Timespan	2015-2022
Sources (Journals, Books, etc.)	1,334
Documents	3,823
Annual growth rate %	18.19
Document average age	3.68
Average citations per document	9.908
References	135,193
Document contents	
Keywords plus (ID)	9,892
Author's keywords (DE)	8,138
Authors	
Authors	10,419
Authors of single-authored docs	483
Authors collaboration	
Single-authored docs	524
Co-authors per document	3.44
International co-authorships %	16.19
Document types	
Article	1,878
Book	29
Book chapter	362
Conference paper	1418
Review	136

TITLE-ABS-KEY ("augmented reality") AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SUBJAREA, "soci"))

The following exclusion and inclusion criteria are applied:

1. Studies should be published in English.
2. Studies were categorized into social sciences and education.
3. Studies should be published between 2015-2022.

3,903 studies were located as a direct consequence of the search that was conducted using the given parameters. In the format known as BibTeX, the bibliometric data of the studies that were acquired were downloaded. After converting the work file to Excel format, a search was conducted to identify any instances of previously published research that had been duplicated. There were discovered to be 13 duplicate studies. Because 67 of the papers had no authors, they were excluded from the analysis of the data. The Biblioshiny App, which is an application included in the Bibliometrix package version 4.1, was utilized in order to carry out the data analysis. R was used in the creation of this package. Bibliometrix is a tool that is both extensive and powerful, and it is used to undertake bibliometric analysis (Aria & Cuccurullo, 2017).

FINDINGS

The findings were presented within the framework of the research questions.

What is the Trend in the Publication of Augmented Reality?

In total, 3,823 studies were investigated for this study (Table 1). The years 2015 to 2022 were the focus of the research that was conducted. The documents came from a total of 1,334 distinct sources. 1,878 journal articles (49.1%), 1,418 conference papers (37.1%), 362 book chapters (9.5%), 136 reviews (3.6%), and 29 books (0.8%) were a part of these investigations. The studies included a total of 9892 indexed keywords in addition to 8,138 author's keywords. There are a total of 10,419 different authors. The total number of authors for documents with a single author is 457, and the total number of documents with a single author is 501. 0.37 documents are attributed to each author, and 2.76 authors are attributed to each document. Co-authors per document are 3.44.

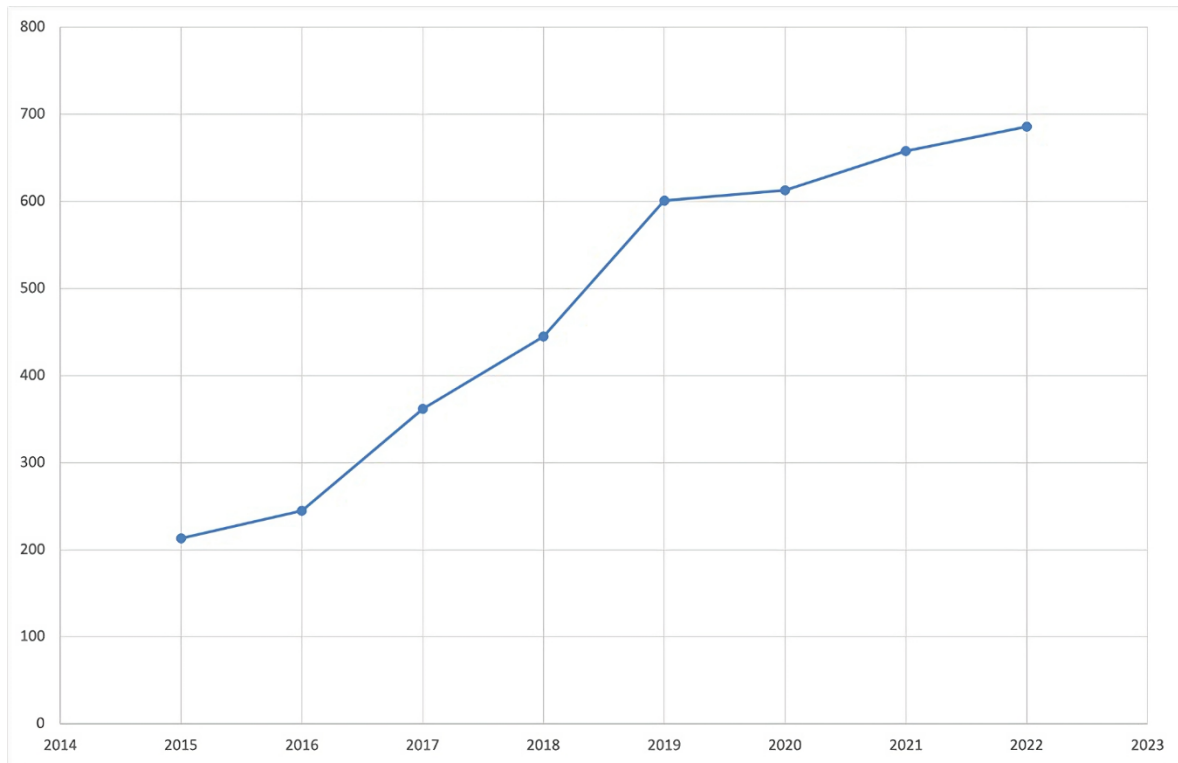


Figure 2. Annual scientific production of augmented reality (Source: Authors' own elaboration)

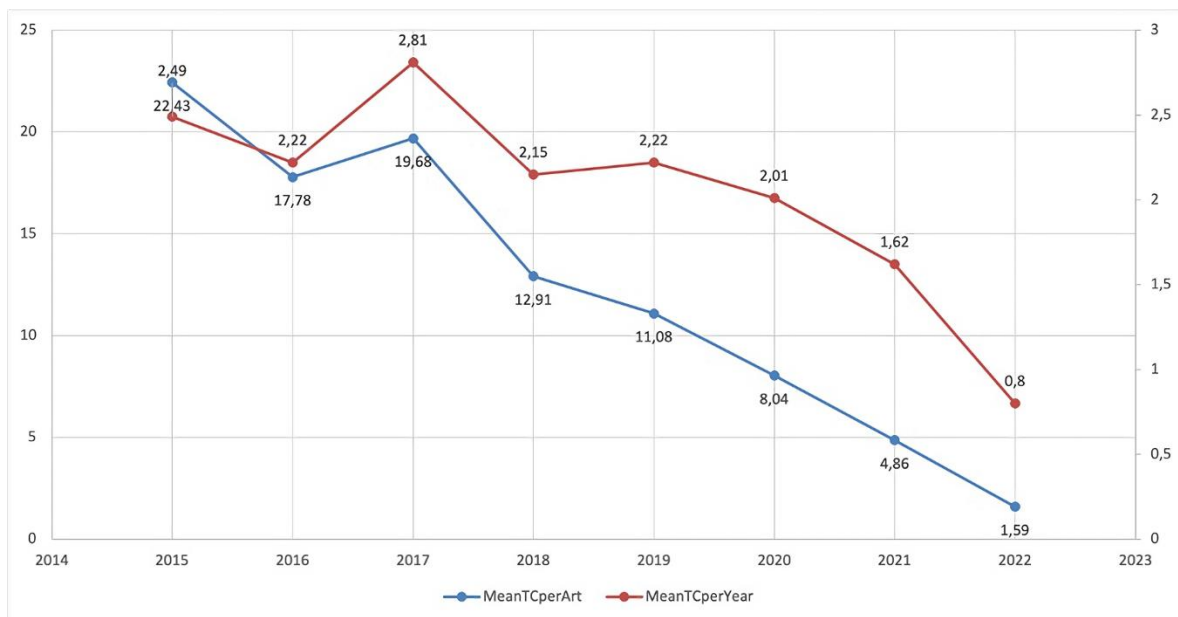


Figure 3. Mean total citation over year and article (Source: Authors' own elaboration)

There has been an increase in publications over the years. Annual growth rate is 18.19%. The rate of increase between 2019 and 2020 is lower than other years. The rate of increase between the years 2018-2019 is higher than in other years. After 2020, there has been an increase in AR publications (Figure 2).

When the number of citations by years is examined, the citation rate in 2015 covers nine years and received an average of 22.43 citations per document (Figure 3). The average of citations by year was 2.49. Citations do not appear to be distributed in an even manner across all of the publications. The average number of citations per document has decreased over the years because there are fewer years for which more recent publications can be cited. The citation average over the years was 2.81, the highest in the studies published in 2017, and the lowest in the studies published in 2022, with an average of 0.8.

Table 2. Top-10 source based on total citations

#	Sources	Citations
1	Computers & Education	3,793
2	Computers in Human Behavior	1,417
3	Journal of Science Education and Technology	815
4	British Journal of Educational Technology	745
5	Interactive Learning Environments	553
6	Presence: Teleoperators & Virtual Environments	528
7	Virtual Reality	509
8	Journal of Chemical Education	475
9	Procedia Computer Science	468
10	Automation in Construction	458

Table 3. Top publications based on citations

Paper	DOI	TC	TC rank	TC/year	TC/year rank	N TC	N TC rank
Akcayir & Akcayir (2017)	10.1016/j.edurev.2016.11.002	857	1	122.4	1	43.6	2
Potkonjak et al. (2016)	10.1016/j.compedu.2016.02.002	440	2	55.0	6	24.7	8
Gavish et al. (2015)	10.1080/10494820.2013.815221	379	3	42.1	9	16.9	>35
Ibáñez & Delgado-Kloos (2018)	10.1016/j.compedu.2018.05.002	363	4	60.5	5	28.1	5
Dwivedi et al. (2021)	10.1016/j.ijinfomgt.2020.102168	352	5	117.3	2	72.4	1
Martín-Gutiérrez et al. (2017)	10.12973/eurasia.2017.00626a	348	6	49.7	7	17.7	>35
Klerkx et al. (2019)	10.1016/j.njas.2019.100315	342	7	68.4	3	30.9	4
Yung & Khoo-Lattimore (2019)	10.1080/13683500.2017.1417359	307	8	61.4	4	27.7	6
Jung et al. (2015)	10.1016/j.tourman.2015.02.013	244	9	27.1	>35	10.9	>35
Portman et al. (2015)	10.1016/j.compenvurbsys.2015.05.001	212	10	23.6	>36	9.5	>35
tom Dieck & Jung (2018)	10.1080/13683500.2015.1070801	210	>35	35.0	10	16.3	>35
Loureiro et al. (2020)	10.1016/j.tourman.2019.104028	190	>35	47.5	8	23.6	10
Dwivedi et al. (2022)	10.1016/j.ijinfomgt.2022.102542	57	>35	28.5	>35	35.9	3
Sirakaya & Alsancak Sirakaya (2022)	10.1080/10494820.2020.1722713	41	>35	20.5	>35	25.9	7
Hwang & Chien (2022)	10.1016/j.caeai.2022.100082	39	>35	19.5	>35	24.6	9

Computer & Education comes in first place when the top ten publications are ranked according to the total number of citations received by each publication (Table 2). The Computer in Human Behavior Journal came in second place. It should come as no surprise that the majority of technology journals are represented among the top ten. The Journal of Chemical Education is the only one of these sources that does not primarily deal with technology as its topic of discussion.

The Most Influential Publications in Augmented Reality

In order to evaluate the influential of the publications, we assessed at the total number of citations, the ratio of the total number of citations to the year, and the normalized citation (Table 3). The research paper "Advantages and challenges associated with AR for education: A systematic review of the literature" by Akcayir and Akcayir (2017) comes out on top both in terms of the total number of citations and the number of citations that it receives each year. The research paper by Potkonjak et al. (2016) with the title "Virtual laboratories for education in science, technology, and engineering: A review" received a total of 440 citations, placing it in second place. After the data have been normalized, the research conducted by Dwivedi et al. (2021) and titled "Setting the future of digital and social media marketing research: Perspectives and research propositions" comes in first. When the results of the ranking are normalized, the publication with the title "Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective" (Hwang & Chien, 2022), which received a total of 39 citations in the list, is included in the top ten list. On the other hand, the research conducted by Gavish et al. (2015) ranked among the top three in terms of the total number of citations, but it did not make the top ten list after the rankings were normalized.

Who Are the Top Authors in Augment Reality?

To determine the activities of the authors in accordance with the number of citations they have received, the h-index, q-index, m-index, and total citation counts were investigated (Table 4).

Table 4. Top-authors based on some indexes

Element	h-index	h-index rank	g-index	g-index rank	m-index	m-index rank	TC	TC rank	NP	PY start
tom Dieck M. C.	8	3	9	11	1,14	1	648	3	9	2017
Jung T.	8	2	8	16	0,89	12	564	5	8	2015
Chen C.	8	1	10	6	1,00	2	433	17	10	2016
Wang Y.	7	6	17	2	0,78	20	631	4	17	2015
Billinghurst M.	7	4	10	7	0,78	21	402	22	10	2015
Cai S.	7	5	17	1	0,88	13	296	>30	22	2016
Lee J.	6	10	9	13	1,00	3	87	>30	11	2018
Mantri A.	6	13	11	4	0,75	22	136	>30	15	2016
Tsai C.-H.	6	14	11	5	0,75	23	159	>30	11	2016
Birt J.	6	7	9	12	0,75	24	136	>30	9	2016
Liu Y.	6	12	11	3	0,67	>30	253	>30	11	2015
Delgado-Kloos C.	5	15	6	>30	0,56	>30	513	6	6	2015
Ibáñez M.-B.	4	>30	4	>30	0,50	>30	507	7	4	2016
Jenny B.	4	>30	4	>30	1,00	4	36	>30	4	2020
Dwivedi Y.-K.	3	>30	3	>30	1,00	6	420	18	3	2021
Kumar A.	3	>30	4	>30	1,00	5	23	>30	7	2021
Guo Y.	3	>30	3	>30	1,00	7	11	>30	3	2021
Akcayir G.	1	>30	1	>30	0,14	>30	857	1	1	2017
Akcayir M.	1	>30	1	>30	0,14	>30	857	2	1	2017

Table 5. Affiliations' rank based on total publications

Affiliation	Articles
National Taiwan Normal University	55
Beijing Normal University	48
Universitas Negeri Malang [Malang State University]	32
Universiti Teknologi Malaysia [University of Technology Malaysia]	30
National Taiwan University of Science and Technology	26
Arizona State University	22
Monash University	22
Nanyang Technological University	22
University of the Aegean	22

According to the h-index, the authors Chen, Jung, and tom Dieck are positioned in the top-three lists because each of them received eight points. One of these authors, tom Dieck, currently holds the number one spot in the m-index and the number three spot with 648 citations in the overall number of citations. Akcayir and Akcayir are the authors who come in first and second place, respectively, in terms of the total number of citations. These authors have a publication that was found in the articles that were scanned. Cai and Wang are currently in first and second place, respectively, according to the g-index. The authors of these studies have produced a total of 22 and 17, respectively, of studies.

Which Countries and Institutions Have Contributed to Research in Augmented Reality?

When the total number of publications of the institutions according to the institutions to which the corresponding authors are affiliated (Table 5), National Taiwan Normal University is in first place with 55 publications. Beijing Normal University is in second place with 48 publications. Universitas Negeri Malang is in third place, while Arizona State University, Monash University, Nanyang Technological University, and the University of the Aegean are at the bottom of the top 10 list with 22 publications.

The USA ranks first in terms of the total number of publications, whereas China ranks first in terms of multi-country publications (Figure 4). This is due to the fact that the co-authors are evaluated according to whether they are from a single country or more than one country. Multi-country publications can be found in each of the countries featured on the top country list. It should be understood that researchers working on AR are more open to working together in terms of publishing joint works.

We looked at the total number of citations received by the publications in each country as well as the average number of citations per article (Figure 5). According to the total number of citations, China was in the first place, while the USA was in second place. Macedonia came in first place, while Israel came in second

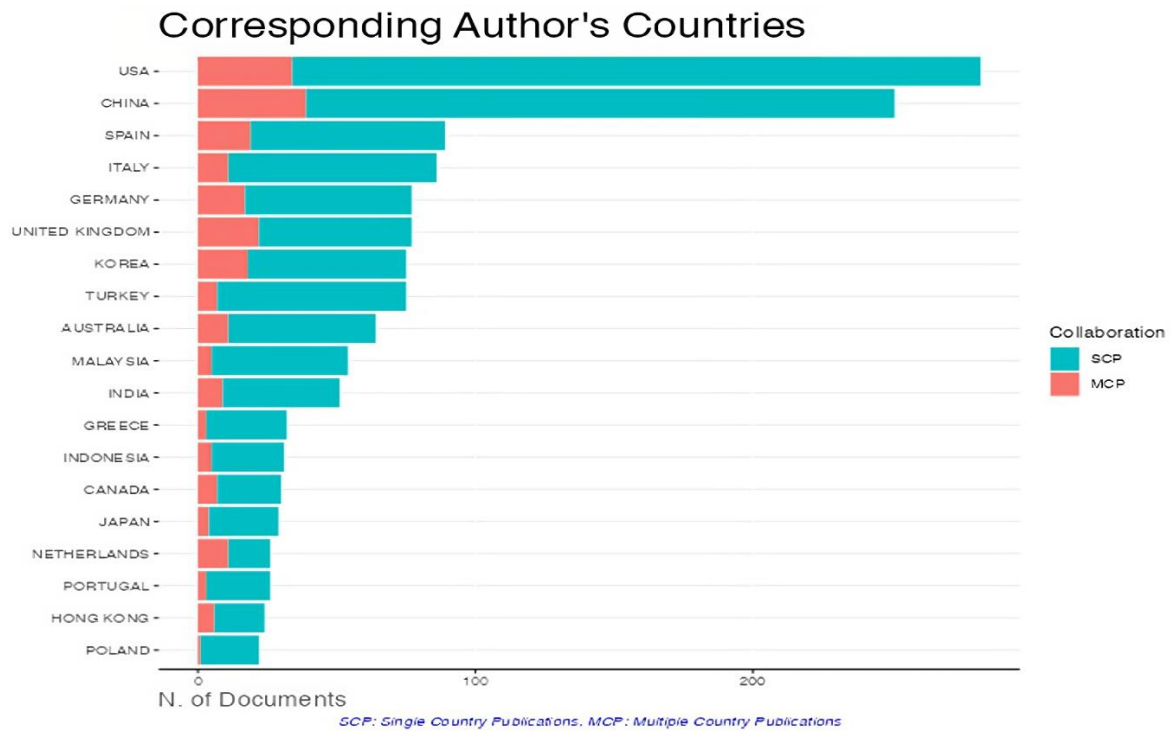


Figure 4. Top-countries based on the numbers of publication (Source: Authors' own elaboration)

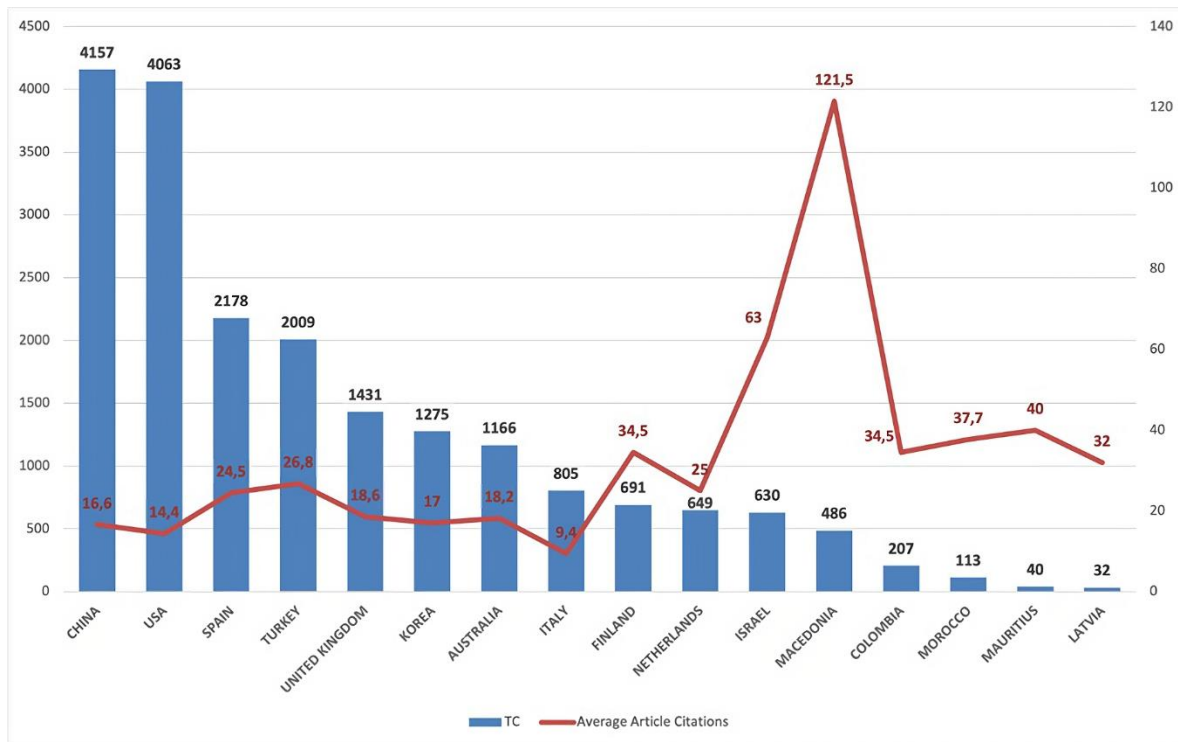


Figure 5. Top-countries based on the total citations and average article citations (Source: Authors' own elaboration)

place, according to the average number of article citations. When examining the contributions of countries, it is important to consider both of these parameters so that an evaluation can be made.

Which Are the Research Front and Intellectual Base of Augmented Reality?

As a result of the cluster analysis made according to the keywords used in the publications, three clusters were formed (Figure 6).

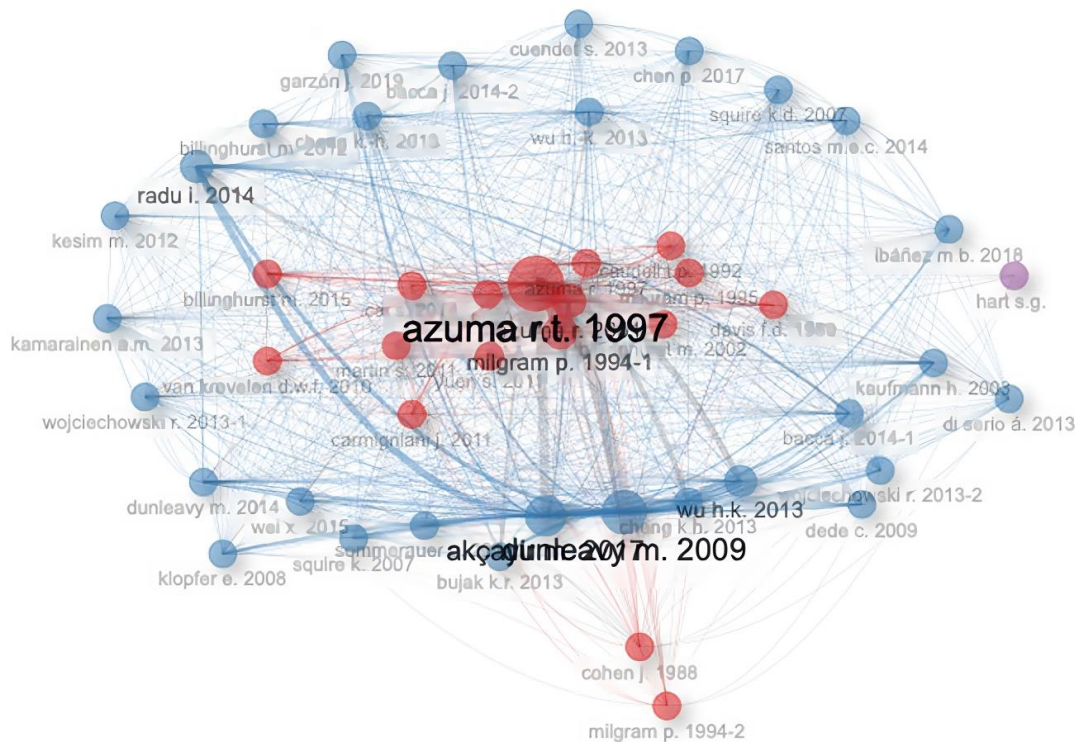


Figure 8. Co-network based on publication (Source: Authors' own elaboration)

The importance of focusing on these topics is strategic. The themes “AR, reality augmented, and VR” in the lower-right quadrant are not well developed but are highly related to themes in other quadrants. They are essential but undeveloped. The themes “American chemical, chemical society, and chemical education” in the upper-left quadrant are well-developed but lack strong connections to other themes in the other quadrants. They are peripheral to the structure of the research field of AR but are well-developed. “architectural design, computer aided, aided architectural” in the lower left quadrant are neither highly developed nor related to other themes in other quadrants. Consequently, they are insignificant in terms of research field’s structure.

In bibliographic coupling, the degree of similarity between two publications is determined by the number of documents that cite both of them separately, whereas in co-citation, it is determined by the number of documents that cite both of them together (Figure 8). According to the analysis of co-citations, two clusters were formed. In the center of the blue cluster are sixteen studies. The best two articles are authored by Azuma (1997) and Milgram and Kishino (1994). There are 29 studies on the red cluster, as well as Dunleavy et al. (2009) and Akçayir and Akçayir (2017).

When the authors’ levels of collaboration with one another are analyzed, fourteen distinct clusters become apparent (Figure 9). There are a total of 13 authors that make up the group, with Cai serving as the focal point. The level of cooperation that existed between the authors is represented visually by the thickness of the lines. Therefore, the relationship between Pombo and Marques was the one that was the most intense.

DISCUSSION

In total, 3,823 studies were investigated for this study. The years 2015 to 2022 were the focus of the research that was conducted. The majority of documents are journal articles. 0.37 documents are attributed to each author, and 2.76 authors are attributed to each document. Co-authors per document are 3.44. There has been an increase in publications over the years. Annual growth rate is 18.19%. After 2020, there has been an increase in AR publications. When number of citations by years is examined, the citation rate in 2015 covers nine years and received an average of 22.43 citations per document. Average of citations by year was 2.49.

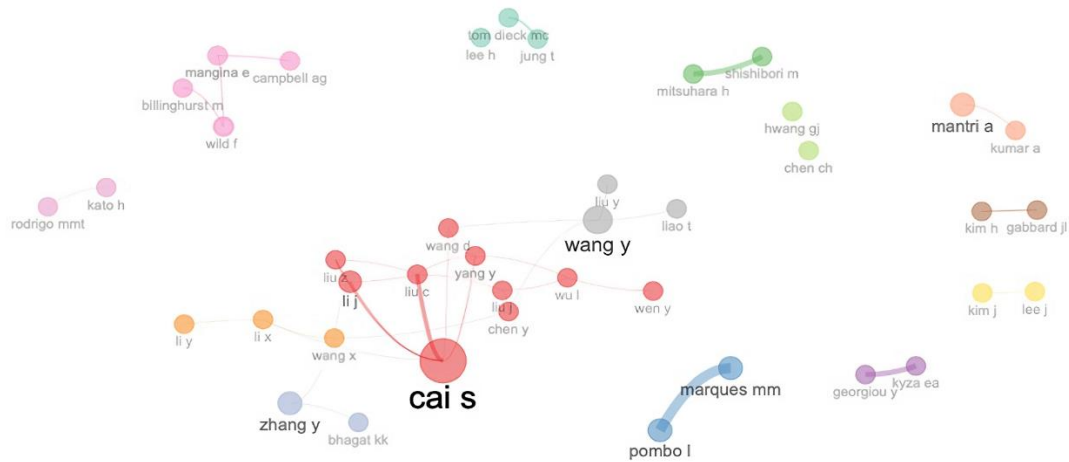


Figure 9. Co-network based on authors (Source: Authors' own elaboration)

"Computer & Education" comes in first place when the top ten publications are ranked according to the total number of citations received by each publication. In some of the bibliometric studies (Garzón, 2021; Karakus et al., 2019), Computer & Education was the most widely published resource. The authors may have preferred Computer & Education because the subject of AR includes technology intensively and is compatible with the scope of Computer & Education.

The research article "Advantages and problems associated with AR for education: A comprehensive review of the literature" by Akcayir and Akcayir (2017) earns the most citations overall and annually. The research by Akcayir and Akcayir (2017) is included on the list of influential articles in a similar study (Garzón, 2021). When the data have been normalized, the research titled "Setting the future of digital and social media marketing research: Views and research propositions" by Dwivedi et al. (2021) is inserted first. The paper with the title "Definition, roles, and possible research challenges of the metaverse in education: An artificial intelligence viewpoint" (Hwang & Chien, 2022) is among the top ten when the ranking results are normalized.

The h-index, q-index, m-index, and total citation counts were analyzed in order to identify the activities of the authors in line with the number of citations they have received. The h-index places writers Chen, Jung, and Tom Dieck in the top three rankings for their respective works. The authors' work has been referenced in bibliometric and systematic analytic studies (Garzón, 2021; Loureiro et al., 2020) to varying degrees. One of these authors, Tom Dieck, is now ranked first in the m-index and third overall. He also holds the place that is designated as number three. The writers Akcayir and Akcayir emerge in first and second position, respectively, when the total number of citations is taken into consideration. According to the g-index, Cai and Wang are in top and second place, respectively, at the moment. According to the findings of another study (Santosa et al., 2021), Cai is among the most influential authors.

National Taiwan Normal University is in the first position when the total number of publications of the institutions is ranked according to the institutions with which the corresponding writers are associated. The university has produced 55 different research. According to additional research (Karakus et al., 2019; Loureiro et al., 2020), National Taiwan Normal University is positioned at the very top of the ranking list. The number of articles produced by Beijing Normal University that is in the best global universities list puts it in the second position.

The USA ranks first in terms of the total number of publications, whereas China ranks first in terms of multi-country publications. According to the findings of the studies (Hincapie et al., 2021; Karakus et al., 2019; Santosa et al., 2021), the USA and China are at the top list based on the total publication. It should be understood that researchers working on AR are more open to working together in terms of publishing joint works. We looked at the total number of citations received by the publications in each country as well as the average number of citations per article. According to the total number of citations, China was in the first place, while the USA was in second place. Macedonia came in the first place, while Israel came in second place, according to the average number of article citations.

The Russian higher education system is undergoing global transformations focused on the construction and distribution of an intelligent environment. AR and other educational technology can contribute to these changes (Isaeva et al., 2021). In Russia, AR research (Anamova & Dubrovin, 2022; Prilepko et al., 2022) are conducted. It will be more effective in this field if it conducts more thorough and collaborative research with other nations.

The findings of the cluster analysis that was performed based on the keywords that were utilized in the articles led to the formation of three clusters. The size of the node in the graphic represents the frequency with which the term was utilized, and the lines represent the typical application. Within the first cluster, the term "AR" occupies the prime position in the middle. The concept of "VR" occupies the pivotal position in the second category. The third cluster was dedicated to the collection of individual characteristics. "AR" and "VR" were found to be two separate clusters in the research conducted by Karakus et al. (2019).

The centrality and density of the most essential issues are shown on the strategic map. The terms "AR technology," "AR applications," and "student learning" are all examples of keywords that are connected to and fundamental to other subjects, respectively. The relevance of concentrating on these subjects is crucial from a tactical standpoint. The concepts of "enhanced reality," "reality augmented," and "VR" are located in the lower-right quadrant. These concepts have not been thoroughly explored, but they have a strong connection to the concepts found in the other quadrants. They are necessary, but not yet fully evolved. Although the topics "American chemistry, chemical society, and chemical education" in the upper-left quadrant have been thoroughly explored, there is a dearth of substantial linkages between them, and the topics discussed in the other three quadrants. While they are not important to the framework of the study field of AR, their development has progressed significantly. The topics "computer-assisted architectural design," "aided architectural," and "architectural design," which are located in the bottom left quadrant, are neither well developed nor connected to the topics that are located in the other quadrants. The findings of a bibliometric study that was carried out by Garzón (2021) indicate that game-based learning and gamification have emerged as prominent trends. In the research carried out by Santosa et al. (2021), the keywords education and learning emerge as some of the most prominent, in addition to the keyword AR. As can be seen from the aforementioned illustrations, it is believed that it will be crucial for future research to focus on the application of goods to educational and learning goals rather than the structural design of AR systems.

According to the co-citations analysis, two clusters occurred. There are sixteen studies in the blue cluster. Studies conducted by Azuma (1997) and Milgram and Kishino (1994) come to the fore. There are 29 publications in the red cluster. In this cluster, Dunleavy et al. (2009) and Akcayir and Akcayir (2017) studies come to the fore. This result is compatible with the study conducted by Garzón (2021). When the levels of collaboration amongst the writers are evaluated, fourteen unique groupings emerge. The group is comprised of thirteen authors, with Cai functioning as the central figure. According to the research (Santosa et al., 2021), Cai is the most prolific author with 10 publications. The thickness of the lines graphically represents the extent of collaboration between the writers. Hence, the link between Pombo and Marques was the most significant. They are co-authors of a number of research.

CONCLUSION

For this analysis, 3,823 studies in total were examined. The research was concentrated on the period from 2015 to 2022. Over time, there has been an increase of publications. The growth rate yearly is 18.19%. There will be more publications about AR after 2020. There were 2.49 citations every year on average. When the top ten publications are ordered by the total number of citations each publication has earned, Computer & Education comes in first. The most citations are received both yearly and total by Akcayir and Akcayir (2017). The study conducted by Dwivedi et al. (2021) is placed first after the data have been standardized. When the rankings are adjusted, the paper (Hwang & Chien, 2022) is in the top-ten. Chen, Jung, and tom Dieck are the top three writers for their respective works according to the h-index. tom Dieck is now placed third overall and first in the m-index. Cai and Wang are currently in first and second place, respectively, according to the g-index. When the total number of publications of the universities are sorted according to the institutions with which the corresponding writers are linked, National Taiwan Normal University comes in first and Beijing Normal University comes in second.

In terms of overall publications, the USA comes in top, whereas China comes in first for publications that span many nations. Both the overall number of citations obtained by the publications in each nation and the typical number of citations per article were examined. China was in first place while the USA was in second place in terms of the overall number of citations. According to the average number of article citations, Macedonia came in #1 and Israel came in second. Three groups were created as a result of the results of the cluster analysis that was conducted using the keywords used in the articles. The phrase "AR" is prominently displayed in the midst of the first cluster. In the second category, the idea of "VR" serves as the focal point. The strategic map displays the center and density of the most important concerns. Examples of keywords that are related to and essential to other topics are "student learning," "AR applications," and "AR technology," respectively. The tactical importance of focusing on these issues cannot be overstated. The lower-right quadrant contains the terms "AR," "VR," and "enhanced reality." Although these ideas have not been completely investigated, they are closely related to those in the other quadrants. They are still evolving, but they are still vital. The upper-left quadrant's "American chemistry," "chemical society," and "chemical education" themes have all been extensively examined, but there aren't many strong connections between them, and the subjects covered in the other three quadrants. While they are not crucial to the structure of the AR research area, they have made great strides in development. The bottom left quadrant contains the themes "computer-assisted architectural design," "aided architectural," and "architectural design," none of which are very well developed or related to those found in the other quadrants. Two groups emerged from the co-citations study. Studies by Azuma (1997) and Milgram and Kishino (1994) are prominent in the blue cluster. Studies by Akcayir and Akcayir (2017) and Dunleavy et al. (2009) are highlighted in the red cluster.

Recommendations and Limitations of the Study

Theme-based learning studies and AR might be prioritized by researchers that want to work on AR based on the findings of the bibliometric analysis. It is advised that researchers who are thinking about doing bibliometric analysis on AR undertake investigations using several databases. When duplicate entries and publications with no authors were found in the data received from the electronic database search method, the required changes were done. Nevertheless, it was not personally checked again to see if each publication is indeed connected to AR. This is a major limitation of the study.

Author contributions: All authors were involved in concept, design, collection of data, interpretation, writing, and critically revising the article. All authors approved the final version of the article.

Funding: The authors received no financial support for the research and/or authorship of this article.

Ethics declaration: Authors declared that the study did not require ethics committee approval since it was based on data from the existing literature.

Declaration of interest: Authors declare no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

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