



Global Research on Augmented Reality in Education: Bibliometrics Analysis

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Abstract

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This research aims to analyze bibliometrics related to Augmented Reality (AR) in the field of education which focuses on the number of citations, classification based on aspects (field, journal, researcher), the relationship between augmented reality topics and other topics, and the relationship between authors who research on the topic augmented reality. The method used in this research uses the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method. The research results show that the number of citations on the topic of Augmented Reality is 48,823. Quality Education is ranked first based on the field of (SDGs) with a total of 2461 articles and the journal AIP Conference Proceedings is the journal that publishes the most articles on the topic of augmented reality. The results of visualization analysis using Vosviewer, produce the latest research topic trends such as augmented reality being linked to medical education, and some topics have not been widely researched such as augmented reality being linked to preschool children.

Keywords:

Augmented Reality, Bibliometrics, Education, PRISMA

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INTRODUCTION

The newest technology that links digital information to a physical world is called augmented reality, or AR (Castañeda et al., 2018). According to Dutta, Mantri, & Singh (Dutta et al., 2022), A technology known as augmented reality makes it possible to observe 3D virtual things interactively in the real environment. AR is now developing at a very fast pace and has changed many lives, including those in the educational field. (Suciliyana et al., 2020).

Currently, AR technology is widely used in the fields of gaming, medicine, marketing, military, and education (Chen, 2019). Augmented reality in the field of education has attracted a lot of interest from researchers in various countries, for example, researchers from the University of Central Florida who researched Mind Power: Thought-controlled Augmented Reality for Basic Science Education (Anya Andrews), researchers from Turkey who researched The Effect of Augmented Reality based applications on achievement and attitude towards science courses in distance education process (Çetin & Türkan, 2022), and researchers from Saudi Arabia who researched the effectiveness of using augmented reality (AR) to enhance student performance: using quick response (QR) codes in student textbooks in the Saudi education system (AlNajdi, 2022).



Because mobile devices have made it easier, less expensive, and more efficient for users to access augmented reality than in the past, there has been a surge in interest in study on the subject in recent years (Dutta et al., 2022). Based on search results on web dimensions, Figure. 1 illustrates how interest in augmented reality research has grown.

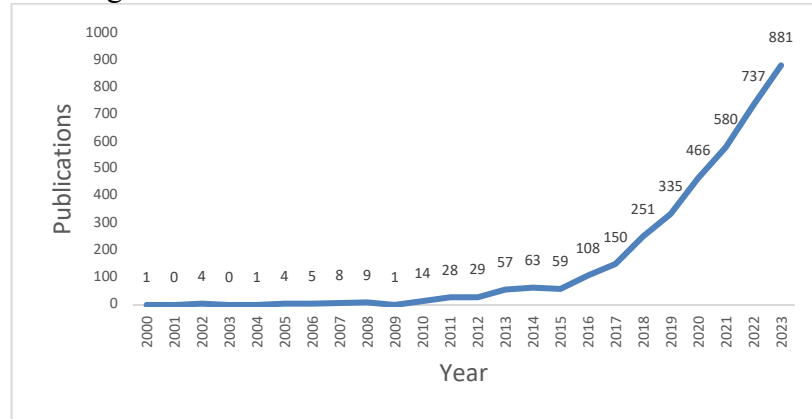


Figure 1. Graph of the increase in the number of publications on augmented reality topics in 2000-2023

According to Figure 1, the number of publications on the topic of Augmented Reality has increased from year to year. Publications produced from 2000-2023 resulted in 3791 publications, with the highest number of publications occurring in 2022, namely 881 publications, meaning that the topic of Augmented Reality is in high demand for research.

Mapping information about augmented reality topics is needed by researchers, especially novice researchers, for example determining the novelty of research on augmented reality topics. This research aims to determine the number of citations on the topic of augmented reality, journals that publish on the topic of augmented reality, researchers who write on the topic of augmented reality, the relationship between the topic of augmented reality and other topics, and the relationship between authors who research on the topic of augmented reality.

The foundation for identifying the most well-known and important articles in a given topic is bibliometrics. (Zyoud et al., 2023). Bibliometrics is now widely used in various domains for mapping and assessing published knowledge and concepts as it has evolved over time (Rana & Pragati, 2022). Apart from that, according to Marín, Belmonte, Campoy, & Rodríguez (Marín-Marín et al., 2019) currently, bibliometrics in the field of Education is not getting all the desired performance, in terms of data collection and individualization. Therefore, it is necessary to carry out research related to bibliometric analysis of global research on Augmented Reality in the field of education.

METHODS

Publication data extracted from <https://app.dimensions.ai/> on March 1, 2024. Articles from the dimensions database are extracted using the PRISMA method

(Page et al., 2021), also known as the Preferred Reporting Items for Systematic Reviews and Meta-Analyses. In Figure. 2, the PRISMA flow diagram is displayed.

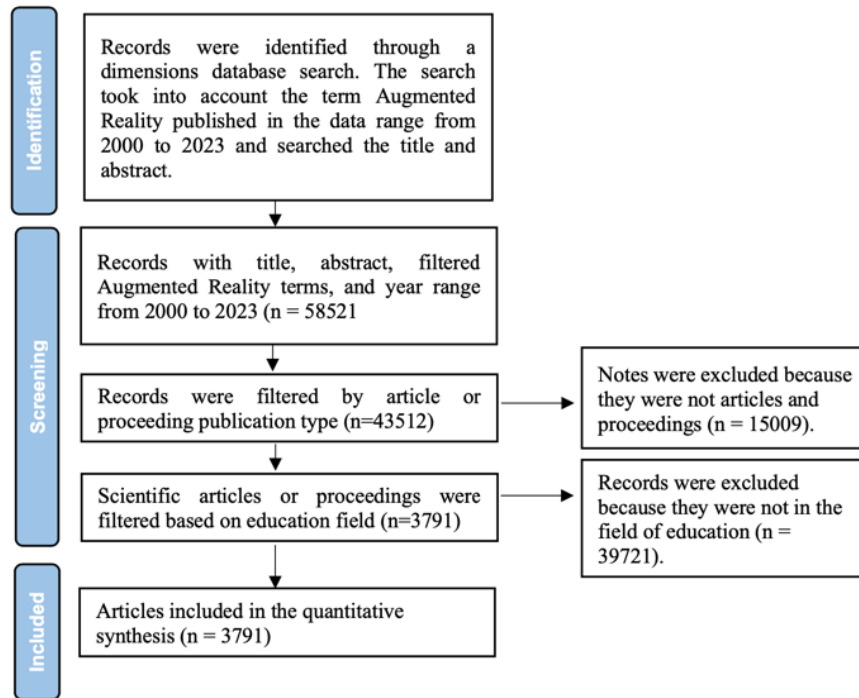


Figure 2. PRISMA Flow Diagram

According to Figure 2, The three steps of the PRISMA approach are identification, filtering, and include. Phase 1 (Identification) first finds 58521 records from <https://app.dimensions.ai/> by searching the title and abstract and using the term "augmented reality" to find publications published between 2000 and 2023. Then, stage 2 (filtering) produced 43512 records by selecting the publication type "articles and proceedings" so that 15009 records were excluded, then filtering was carried out again based on the education sector and obtained 3791 records so that 39721 records were excluded because they were not included in the education sector. Then, Stage 3 (inclusive) resulted in a final sample of 3791 articles. This last sample was then subjected to VOSviewer analysis. A computer tool called VOSviewer is used to create and display bibliometric maps. (van Eck & Waltman, 2010). The selection of the 2000–2023 period in this study is based on several key considerations, particularly in the context of a systematic review using the PRISMA method. This period was chosen to accommodate an adequate amount of literature and ensure that all relevant studies can be identified to support a systematic analysis in this research. Selecting a period that is too short may also reduce the scope of the study and eliminate important insights into the development of the topic of Augmented Reality.

RESULTS & DISCUSSION

This section describes the bibliometric analysis on the Augmented Reality topic extracted from <https://app.dimensions.ai/> in the year range from 2000 to 2023.

In this section, the results and discussion of the Augmented Reality topic analysis are focused on the number of citations, classification based on aspects (field, journal, researcher), network visualization from aspects (co-occurrence, co-authorship), publication clusters in terms of aspects (co-occurrence, co-authorship), overlay visualization, and density visualization will be described.

1. Number of Citations

The number of Augmented Reality citations from 2000 to 2023 is 48823. Furthermore, the number of citations per year is presented in Figure. 3.

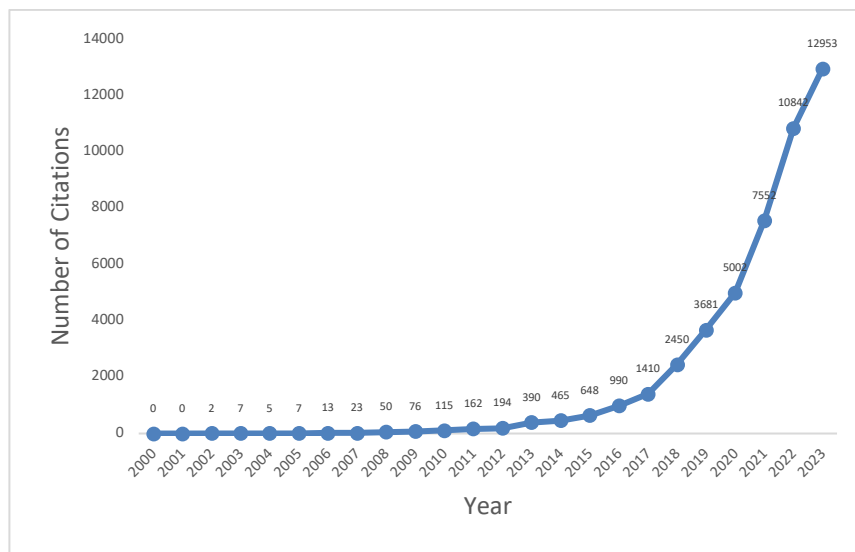


Figure 3. Total number of citations from 2000 to 2023 on the subject of augmented reality in education

According to Fig. 3, the number of citations on the topic of Augmented Reality has increased from year to year. The smallest number of citations occurred in 2000 and 2001 with 0 citations each. Meanwhile, the largest number of citations occurred in 2023 with 12953 citations. Meanwhile, the average citation is 2219,22. Research data reveals that, of 3791 publications, the publication entitled "Current status, opportunities and challenges of augmented reality in education" (Anderson et al., 2014) is the most cited publication with 1443 citations. This article was published in Computer and Education which was indexed by Scopus as being in the first quartile (Q1) with a 2022 SJR of 3,68. Thus, articles published in journals indexed by reputable indexers will be widely cited by other authors. This bibliometric study, in which studies are ranked according to the number of citations they receive, offers data on the influence of research (Pahwa et al., 2022). Thus, this article has an impact so that it can used as a reference in research that reviews the topic of Augmented Reality.

2. Sustainable Development Goals Field

Based on research fields, publications on the topic of Augmented Reality can be grouped. Furthermore, the number of publications based on the SDGs field (7 largest) is presented in Figure 4.

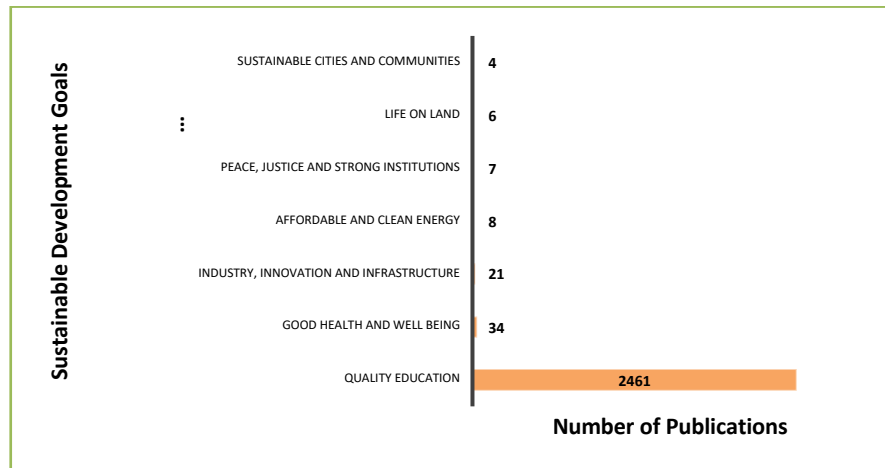


Figure 4. Number of publications on Augmented Reality topics in the education sector in terms of the SDGs sector (Data source: <https://app.dimensions.ai/>)

According to Figure 4, Quality Education is ranked first based on Sustainable Development Goals (SDGs) with 2461 articles. Thus, the topic of Augmented Reality is most widely applied to Quality Education.

3. Journal

Based on journals, publications on the topic of Augmented Reality can be grouped. Furthermore, the number of publications by journal (7 largest) is presented in Figure 5.

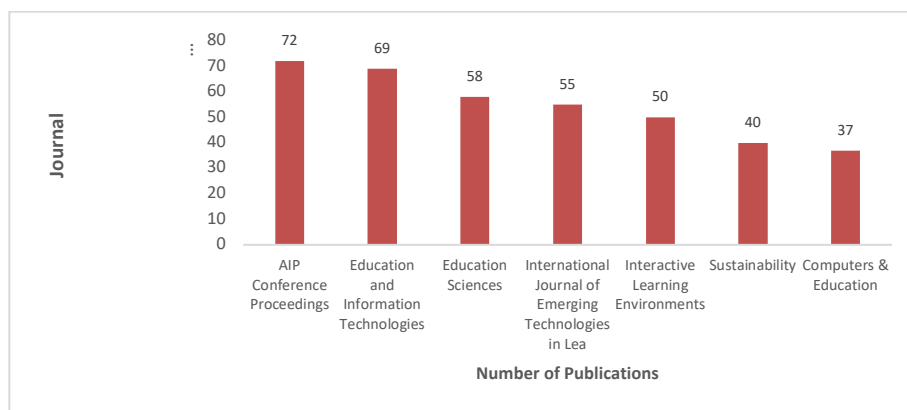


Figure 5. Number of publications on Augmented Reality topics in the field of Education in terms of journals (Data source: <https://app.dimensions.ai/>)

According to Figure 5, AIP Conference Proceedings is ranked first based on journal sources containing the keyword Augmented Reality with 72 articles, followed by the Education and Information Technologies Journal with 69 articles, then the third position is occupied by the Education Sciences journal with 58 articles. So, the most relevant journal coverage for the topic of Augmented Reality is AIP Conference Proceedings.

4. Researcher

Publications can be grouped by researcher. The following is a presentation of the number of publications based on the researchers selected (the 7 largest) which can be seen in Figure 6.

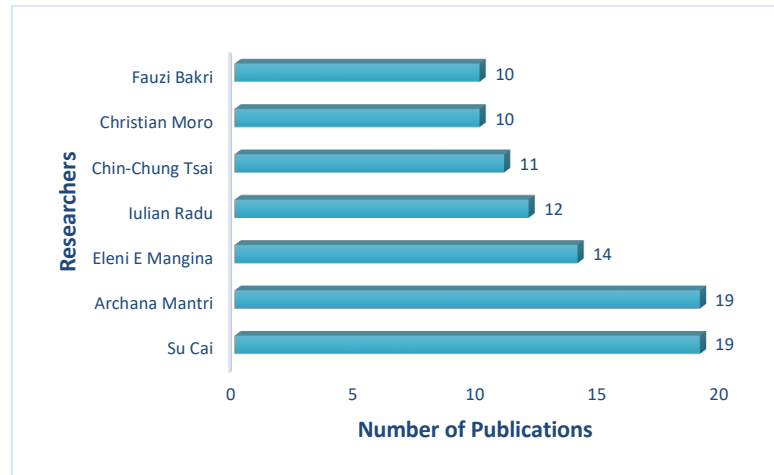


Figure 6. Number of publications on Augmented Reality topics in the field of Education as viewed by researchers (Data source: <https://app.dimensions.ai/>)

According to Figure 6, Su Cai (Beijing Normal University, China) and Archana Mantri (Chitkara University, India) are ranked first with 19 articles each, followed by Eleni E Mangina (University College Dublin, Ireland) with 14 articles, and followed by Iulian Radu (Harvard University, United States) with 12 articles. Thus, Su Cai is the most productive researcher on the topic of Augmented Reality

5. Network Visualization for Co-occurrence

A network visualization map is created from the outcomes of bibliometric analysis using Dimensions information fed into Vosviewer software. Next, network visualization for the co-occurrence of these 191 terms is presented in Figure 7.

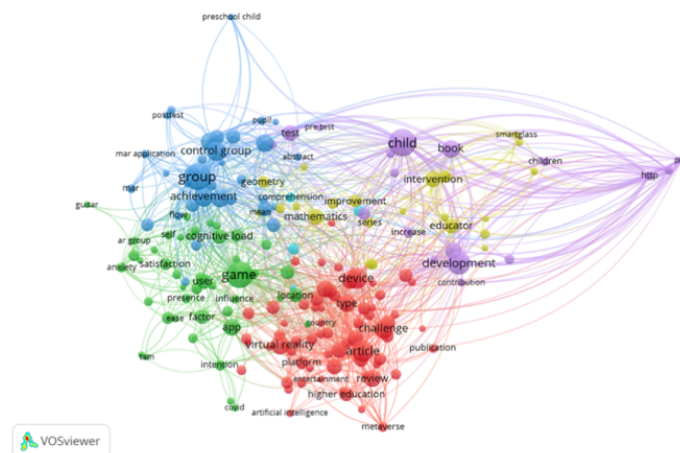


Figure 7. Network visualization on the topic of Augmented Reality in the field of Education

Of the 3791 articles indexed by dimensions, there are 191 terms, 6 clusters, 7711 links, and a link strength of 40324. In Figure 7, A line connecting two terms indicates that they appear together in the title and abstract, for example, "games" and "development". On the other hand, two terms are not connected by a line, indicating that the two terms do not appear together in titles and abstracts such as games and language learning. Thus, researchers can utilize this network visualization to pinpoint new areas of inquiry within the field of study. For example, the term mobile augmented reality is connected to games, and games are connected to language learning, but mobile augmented reality is not connected to language learning. Thus, novelty for research on the topic of augmented reality can further be obtained through research on augmented reality associated with language learning. Another novelty is augmented reality associated with medical education.

Of the 191 terms grouped into 6 clusters consisting of cluster 1 (67 terms), cluster 2 (46 terms), cluster 3 (33 terms), cluster 4 (23 terms), cluster 5 (18 terms), and cluster 6 (4 terms).

6. Overlay Visualization for Co-occurrence

VOSviewer also provides map overlay visualization. The data derived from the Overlay visualization outcomes presented in Figure 8 can serve as a point of reference for recognizing and identifying the cutting edge of augmented reality research conducted between 2000 and 2023. Next, an overlay visualization for the co-occurrence of these 191 terms is presented in Figure 8.

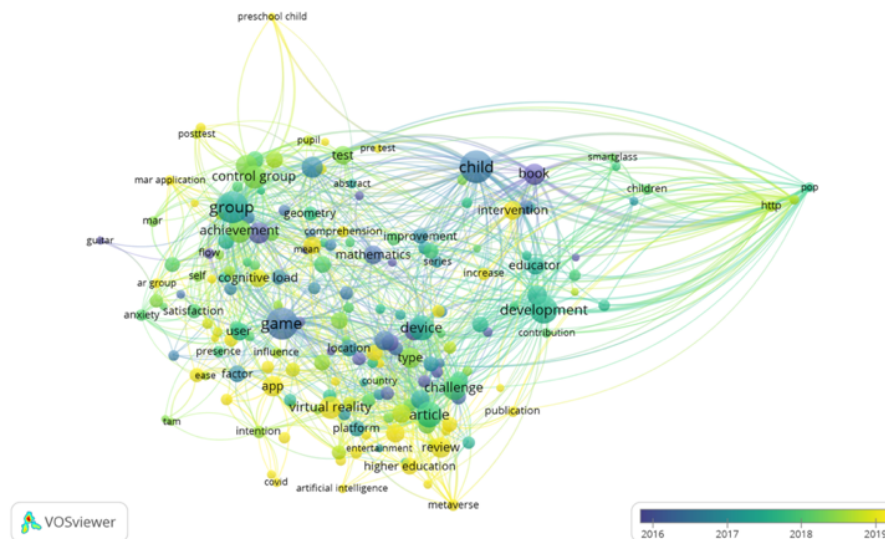


Figure 8. Overlay visualization on the topic of augmented reality

In Figure 8, the overlay visualization on the topic of augmented reality provides analysis based on augmented reality keywords from 2000 to 2023 to observe trends in research titles related to augmented reality. According to Figure 8, terms colored yellow imply that the keyword is of current research interest (Lam et al., 2022). Thus, the current research trend in augmented reality is terms colored

yellow. For example, augmented reality is associated with the metaverse, medical education, higher education and preschool children.

7. Density Visualization for Co-occurrence

In addition, VOSviewer displays a density visualization map. Next, density visualization for the co-occurrence of these 191 terms is presented in Figure 9.

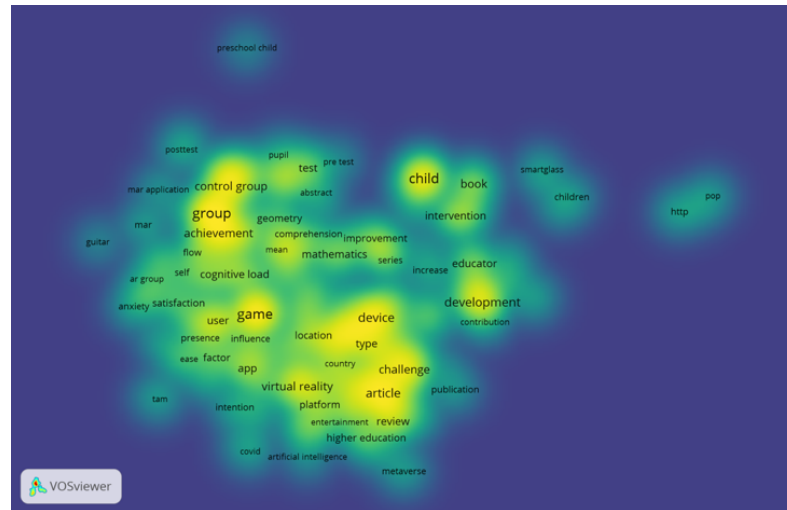


Figure 9. Density Visualization on the Topic of Augmented Reality

In Figure 9, The density level of phrases denoted by a particular hue is visualized in the augmented reality topic's density visualization. While yellow denotes a high density, blue denotes a low density. When a topic has a high density, it has been extensively researched; for instance, the keywords "game," "device," "child," and "challenge". Low density, on the other hand, indicates a lack of widespread investigation on the subject. Research on these subjects, such as the keywords metaverse, higher education, and preschooler, may become possible as a result. In this sense, subjects with density visualization falling into the low group are suggested for further augmented reality research. For example, augmented reality is associated with preschool children.

8. Network Visualization for Co-authorship

Additionally, VOSviewer shows network visualization for co-authorship. Next, network visualization for the co-authorship of 143 authors. In Figure 10, Researchers in the field of augmented reality have a correlation or relationship with one another, as explained by the network visualization for co-authorship. When two authors are linked together, it signifies that they are co-authors of the same paper. Conversely, two writers that are not linked together by a line signify that they do not appear as authors of the same article together. So, authors can be clustered based on their connectedness. One of the authors who is actively conducting research in the field of augmented reality is Archana Mantri from Chitkara University, India with a total of 19 publications on the topic of augmented reality. According to Figure 10, there are 143 authors, 62 clusters, 137 links, and a link strength of 248. The largest set of connected authors consists of 9 authors. In Figure 10, there are

62 clusters consisting of cluster 1 (9 authors), cluster 2 (6 authors), clusters 3, 4, 5 (5 authors), cluster 6-11 (4 authors), cluster 12-17 (3 authors), cluster 18-43 (2 authors), and cluster 44-62 (1 author). Thus, the largest cluster consists of 2 authors.

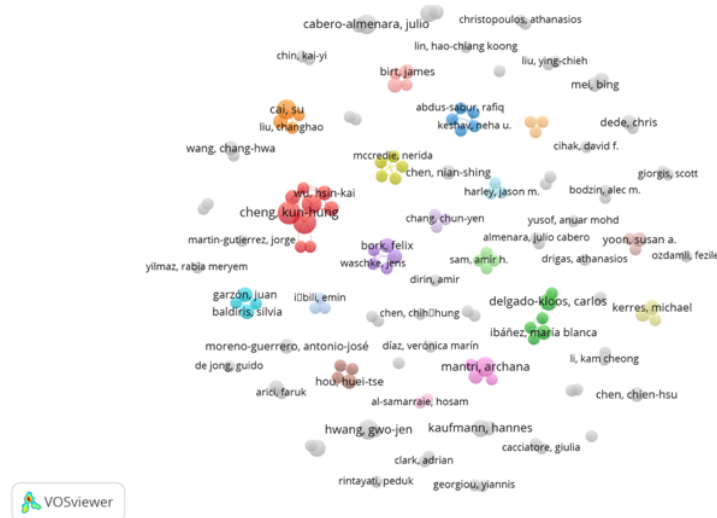


Figure 10. Network visualization for co-authorship on the topic of Augmented Reality in the field of Education

The results of the bibliometric analysis show that the topic of Augmented Reality (AR) in education has experienced rapid development in the last two decades. From the citation data analyzed, it can be seen that the number of citations to AR research continues to increase, with the highest number recorded in 2023 at 12,953 citations. This shows that AR is increasingly receiving attention as a technology that has the potential to increase learning effectiveness. The most cited article, "Current status, opportunities and challenges of augmented reality in education" published in the journal *Computers and Education*, indicates that research related to AR in education has high relevance in the academic community.

This finding is in line with research conducted by (Dendodi et al., 2024) which states that AR not only facilitates the understanding of abstract concepts but also increases student engagement and motivation to learn through a more interesting and enjoyable learning experience. In addition, research by (Rahmadika et al., 2024) examined the use of AR technology in increasing student interest in elementary schools. The results showed that AR was effective in stimulating students' critical thinking patterns and making learning more interesting, thereby increasing their motivation and interest in the subject. Thus, the increasing number of publications and citations in this field indicates that AR continues to develop as an effective pedagogical tool.

In the context of the Sustainable Development Goals (SDGs), this study found that the AR topic was most associated with Quality Education (SDG 4), with a total of 2,461 publications. This strengthens the argument put forward by (Cheng & Tsai 2020), who stated that the implementation of AR in education can improve the quality of learning through interactive visualization and deeper learning

experiences. The increasing number of publications in this field indicates that AR can be a solution to the challenges of 21st-century learning, especially in improving the understanding of complex concepts.

Analysis based on journal sources shows that AIP Conference Proceedings is the source with the largest number of publications on AR in education, followed by Education and Information Technologies and Education Sciences journals. This finding suggests that research on AR in education is widely published in academic conferences, reflecting the ever-evolving and regularly updated nature of this technology.

Furthermore, network visualization analysis shows a strong correlation between various terms in AR research. For example, the term mobile augmented reality is related to game-based learning and language learning, but not directly related to medical education. This suggests new research opportunities that could further explore the relationship between AR and other educational fields, such as medical education or early childhood learning. In terms of term density in the density visualization analysis, it was found that the most frequently appearing terms related to AR were game, device, child, and challenge. Meanwhile, terms such as metaverse, higher education, and preschool child still have low density, indicating that these topics are still under-explored in AR research. This opens up opportunities for future research to further explore the application of AR in the context of metaverse and early childhood education.

Finally, co-authorship analysis shows that researchers such as Su Cai from Beijing Normal University and Archana Mantri from Chitkara University are the most productive researchers in the field of AR with 19 publications each. The existence of a collaborative network between researchers from various countries shows that AR research in education is global and continues to grow through cross-institutional collaboration.

Overall, the results of this study confirm that AR has an increasingly significant role in education and has the potential to continue to develop as a learning technology in the future. The implications of the results of this study can be a reference for researchers to explore areas that have not been widely studied, as well as for education practitioners to adopt AR as part of innovative learning strategies.

CONCLUSION

Several conclusions were drawn from this study, one of which being that there are more publications on the subject of augmented reality every year. The most cited publication on augmented reality is entitled Current status, opportunities and challenges of augmented reality in education, with a total of 1443 citations. Quality Education is ranked first based on Sustainable Development Goals (SDGs) with 2461 articles. The journal that contains the most publications on the topic of augmented reality is the AIP Conference Proceedings journal. The results of the Network visualization analysis for co-occurrence, Overlay visualization, and density visualization produced new findings related to topics that have not been widely researched in the field of augmented reality, for example mobile augmented

reality is associated with language learning, augmented reality is associated with medical education or metaverse, and also augmented reality can be associated with preschool children.

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