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Bibliometric Analysis: Augmented Reality in Science Education Research Trends

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Abstract: This research aims to analyze research trends related to the topic of Augmented Reality in 2019-2023* through bibliometric analysis with the Scopus database. Based on the criteria, 490 articles were obtained from 3906 documents. These articles have been translated from international journals indexed by Scopus. The selection references were then managed using reference management software, namely Mendeley. After working on the database, the researchers classified and visualized it using VOSviewer software. The results show that Augmented Reality research is gradually increasing every year. The United States and Germany contribute the most research globally. Visualizing Augmented Reality research trends for 2019-2023*, there are six clusters. The results of this research can support researchers regarding Augmented Reality research trends in the world and provide direction for further research. Overall, these reflections provide an excellent reference point for further research on Augmented Reality.

Keywords: Augmented reality; Bibliometric analysis; VOSviewer

Introduction

The development of information and communication technology in education, especially the use of instructional media in the teaching and learning process, has seen significant advancements. Technologies such as computers, the internet, e-learning, social media, learning simulations, and more recently, the use of mobile devices, game applications, virtual worlds, and Augmented Reality have been employed (Dewantara et al., 2021; Misbah et al., 2018; Nincarean, 2013; Pulungan & Rakhmawati, 2022). The term "Augmented Reality" was coined by Thomas Caudell and David Mizell in 1990 while they were working at Boeing (Budi & Hariyanti, 2020; Ismayani, 2020). At that time, Augmented Reality was defined as the integration of virtual images into the real world. Augmented Reality is a technology that attempts to merge virtual objects into the real environment, allowing users to interact with virtual objects as if they were part of the real world. Azuma (1997) explained that Augmented Reality creates an environment where users can see the real world overlaid or covered by virtual objects, and both are visible in the same space. Augmented Reality serves as a medium where digital information is added to the physical world, offering various ways to interact with digital information, such as adding, altering, or modifying it in the physical world (Craig & LePeak, 2013; Dunleavy & Dede, 2014; Sungkur et al., 2016).

Augmented Reality is considered a new form of media, combining aspects of ubiquitous computing, tangible computing, and social computing. This medium provides a unique experience by merging the physical and virtual worlds, offering continuous user control and implicit interactivity from various perspectives (Kesim & Ozarslan, 2012; Steffen et al., 2019). Research results

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indicate that the use of Augmented Reality offers unlimited interaction, providing learners with a natural 3D learning experience. Learning media with Augmented Reality has benefits in improving the learning process and students' interest in learning because Augmented Reality can project in a real way and involve the interaction of all students' five senses (Abdullah et al., 2022; Azizah & Setyaningrum, 2022; Mustaqim, 2016; Zulfarina et al., 2021). Educators are encouraged to develop interfaces using Augmented Reality for instructional media. However, this study is limited to discussing Augmented Reality as a new technology with potential applications in education and does not delve into the design and creation of multimedia learning materials using Augmented Reality. Another study Saputro et al. mentioned that utilizing Augmented Reality as an Android-based instructional medium gives learners a different learning experience, boosts their self-confidence, and results in improved learning outcomes (Saputro & Saputra, 2015). The educational experience offered by Augmented Reality is distinct due to several reasons, as mentioned by Billinghurst (2002): support for unlimited interaction between the real and virtual environments, use of real interface metaphors for object manipulation, ability to support multiscale collaboration. The research also indicates that various interfaces can be created by leveraging these three aspects, but better display and input devices are required, achieved by combining Augmented Reality with various interface types for diverse purposes.

Research related to Augmented Reality needs to be expanded across various scientific fields. This is because, over the past five years, only about 3,906 documents related to Augmented Reality publications have been found in the Scopus database. Therefore, bibliometric analysis related to Augmented Reality has been conducted to provide insights into Augmented Reality knowledge, assessing the most cited sources, authors, countries, and keywords related to Augmented Reality. This bibliometric study offers crucial insights into emerging research trends in Augmented Reality. The analysis also identifies networks that may be interesting to explore in terms of research innovation. The article is structured as follows: Section 2 provides information on the methodology used to retrieve documents from the Scopus database, resulting in a bibliometric network. Section 3 presents results and discussions related to Scopus bibliometric data, and Section 4 reviews literature related to the theme involving Augmented Reality based on keyword analysis. The objectives of this research are to answer: the number of Augmented Reality topic publications from 2019-2023, which country publishes the most Augmented Reality topics, keywords associated with Augmented Reality, and the top 5 citations in research.

This research is essential to make it easier for future researchers to read the interpretation of analysis results and map the relationships between keywords in augmented reality. Apart from that, through a thorough analysis of augmented reality, future researchers can research aspects that have never been studied or are rarely studied.

Method

This study is a bibliometric analysis research (Merigó & Yang, 2017; van Nunen et al., 2018). The bibliometric analysis process consists of five stages (Figure 1), including 1) research design; 2) data collection; 3) data analysis; 4) data visualization; and 5) interpretation (Misbah et al., 2022; Rukmana et al., 2023; Zupic & Čater, 2015). Data collection was conducted in October 2023, based on criteria that yielded 490 articles from 3906 documents. These articles were analyzed from international journals indexed in Scopus. Data from Scopus were saved in RIS and CSV formats, and Mendeley Desktop was utilized to rearrange article metadata. VOSviewer software was employed as a bibliometric analysis tool to visualize networks of authors, countries, journals, and keywords (Hakim, 2020; Machmuda et al., 2022; Zakiyyah et al., 2022). This data was input for co-authorship and co-occurrence analyses, producing network maps of authors, countries, journals, and keywords. Additionally, from citation analysis, network maps of scholarly journals were generated. VOSviewer version 1.6.18 was used for constructing and visualizing bibliometric networks. This software provides insights into publication details such as authors, organizations, countries, and keywords. The VOSviewer display serves as a visualization of research trends in Augmented Reality from 2019 to 2023.

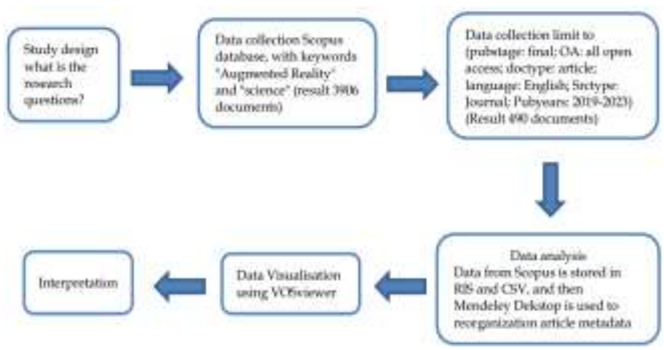

Figure 1. Bibliometric research scheme on the topic of augmented reality

Result and Discussion

The number of Augmented Reality publications from 2019 to 2023 is presented in Figure 2. In Figure 2, the number of publications shows a periodic increase, and an increase is anticipated in 2023. This result aligns with research on other topics indicating an annual increase in the number of publications, such as the Potential of Virtual Reality as a Tourism Marketing Strategy (Prambayun et al., 2022), Digital Media Empowering 21st Century Critical Thinking in Science Learning (Jannah & Atmojo, 2022), and Industry 4.0 Revolution in the Education Sector (Dito & Pujiastuti, 2021).

Based on Figure 2, a search in the Scopus database yielded 490 documents on Augmented Reality from 2019 to 2023. The number of published documents shows a periodic decline in 2020. Cumulative document counts for each year increased over the past 5 years, while annual publication counts decreased in the investigated 2020 period according to Figure 2. Data for 2023 is still being updated; the publication count for that year is expected to increase, as the update is ongoing, considering that October 2023 is within the data collection period.

Indeed, in the last 5 years, research on Augmented Reality has been increasing annually, despite a decline in 2020 compared to 2019. This decline is attributed to the impact of the COVID-19 pandemic in 2020, which led to the implementation of online learning, necessitating adjustments to the learning process that year (Fauzi & Khusuma, 2020; Jojor & Sihotang, 2022; Mamluah & Maulidi, 2021; Novianti, 2020; Widiastuti & Subekti, 2021).

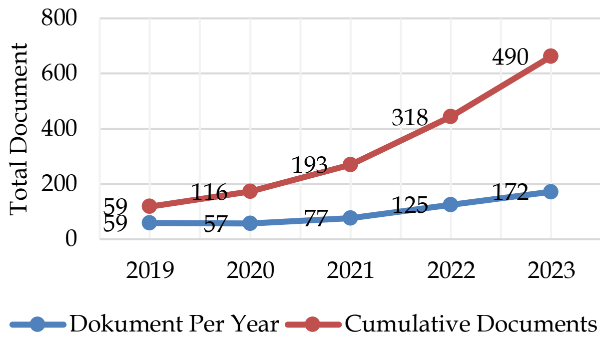

Figure 2. Document publications from year to year on augmented reality

The result of primary publications and research interests based on co-authorship-country-full counting-maximum number of countries per document=25, minimum number of country 5, resulted in the analysis of 28 countries, as presented in Figure 3.

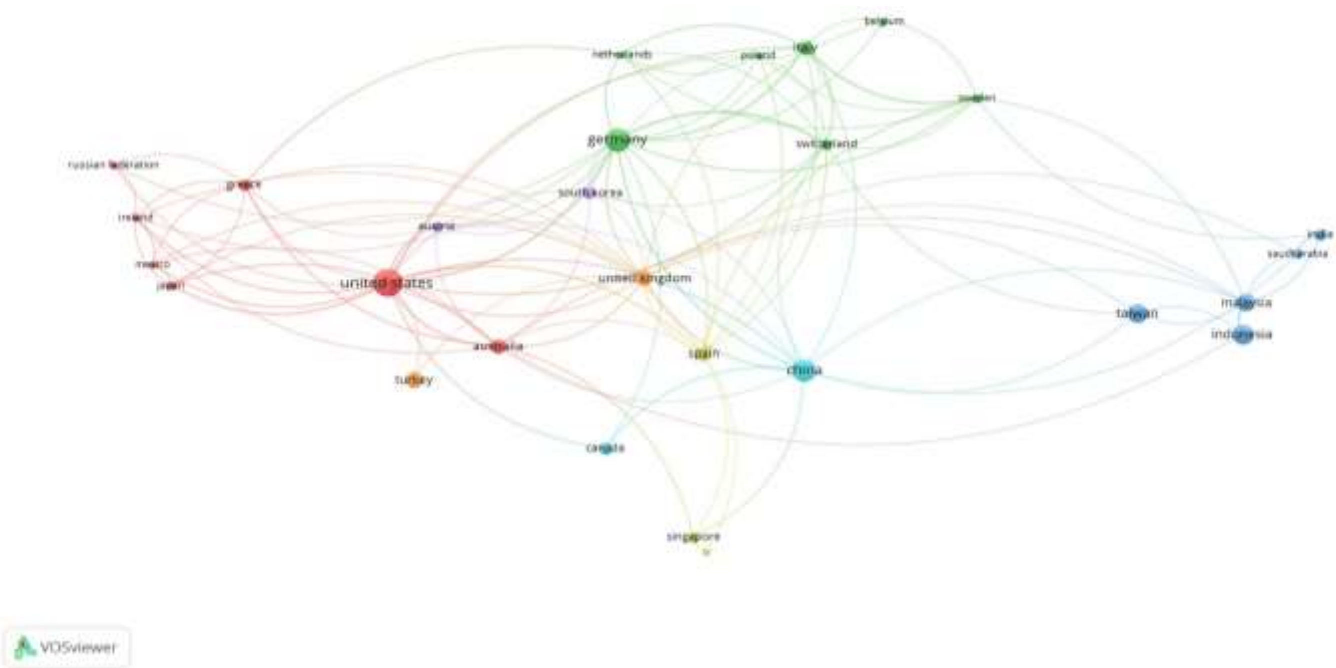

Figure 3. Network visualization augmented reality co-authorship of countries analysis

Figure 3 is classified into 7 clusters of countries. As seen in Figure 4, for Cluster 1, there are countries such as Australia, Greece, Ireland, Japan, Mexico, the Russian Federation, and the United States. The most prominent country in this cluster is the United States, which is also connected to other clusters like Cluster 2 (Germany, Italy, and Switzerland), Cluster 4 (Spain), Cluster 5 (Austria and South Korea), Cluster 6 (Canada and China), and Cluster 7 (Turkey and the United Kingdom). Cluster 1 is marked with the red color.

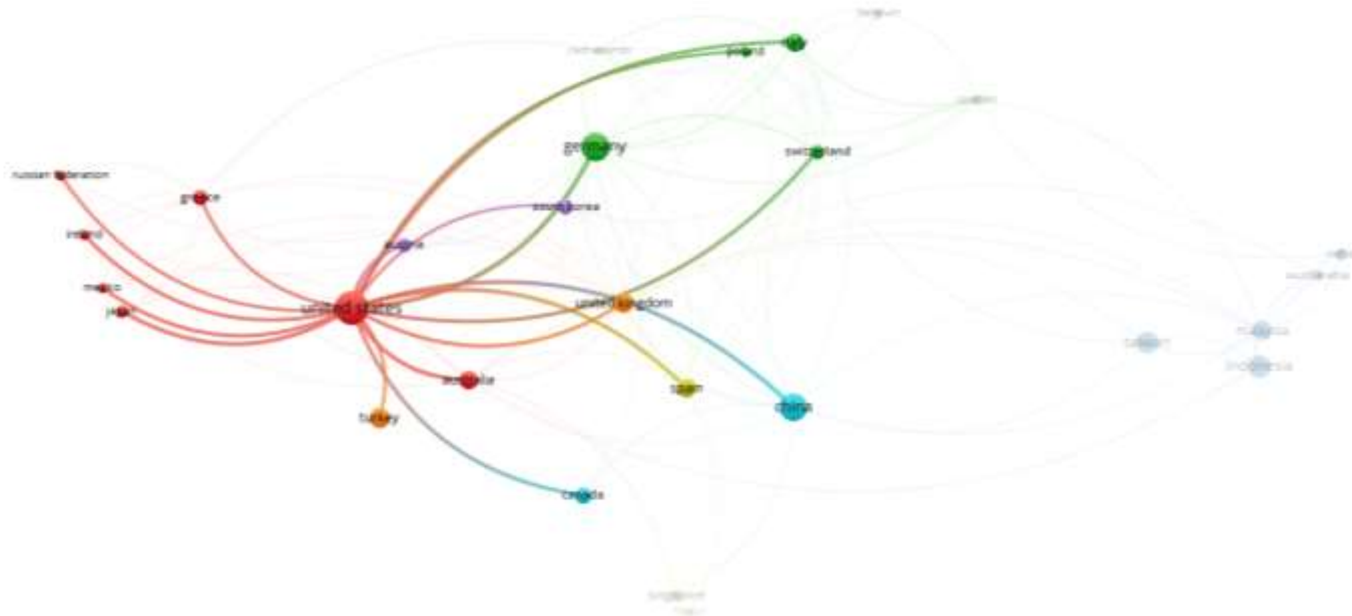

Figure 4. Network visualization Cluster 1 of countries analysis

Cluster 2 includes countries such as Belgium, Germany, Italy, the Netherlands, Poland, Sweden, and Switzerland. Based on Figure 5, the most prominent country in Cluster 2 is Germany. Germany is connected to other clusters such as Cluster 1 (United States, Ireland, and the Russian Federation), Cluster 4 (Spain), Cluster 5 (Austria and South Korea), Cluster 6 (Canada and China), and Cluster 7 (the United Kingdom). Cluster 2 is marked in green.

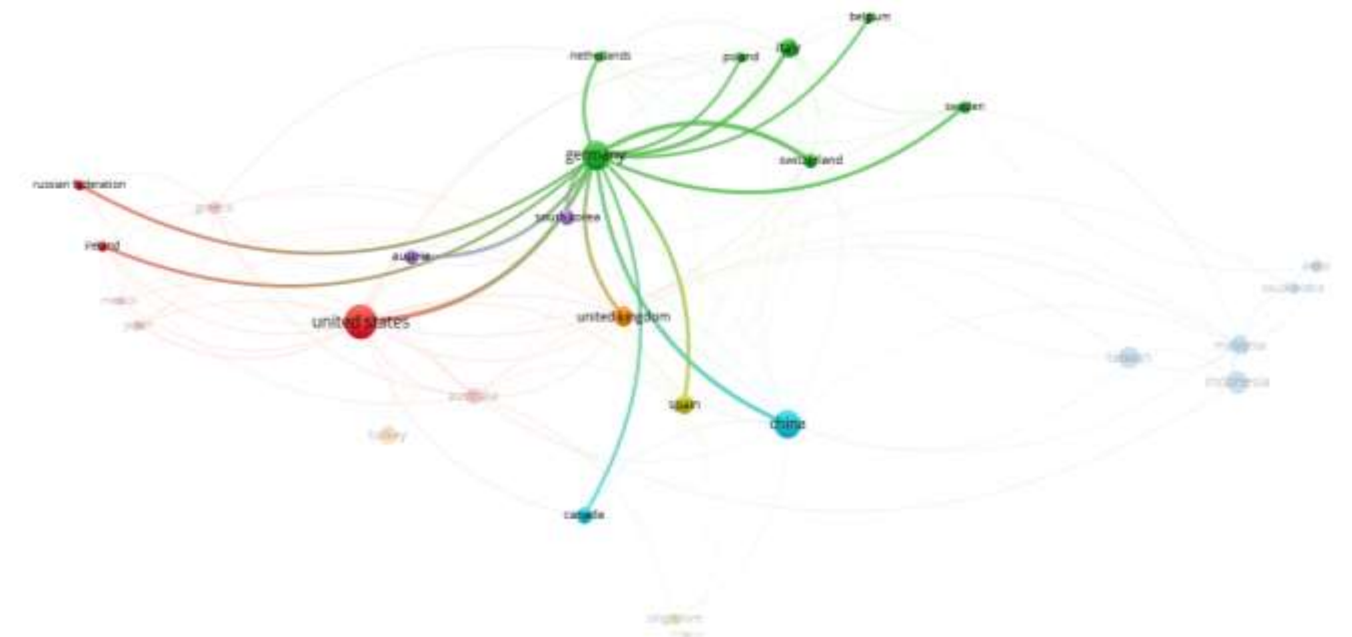

Figure 5. Network visualization cluster 2 of countries analysis

Cluster 3 covers countries such as India, Indonesia, Malaysia, Saudi Arabia, and Taiwan. Based on Figure 6, the most prominent country in Cluster 3 is Malaysia, which is connected to other clusters such as Cluster 1 (Australia), Cluster 2 (Sweden), and Cluster 7 (the United Kingdom). Cluster 3 is marked with the blue color.

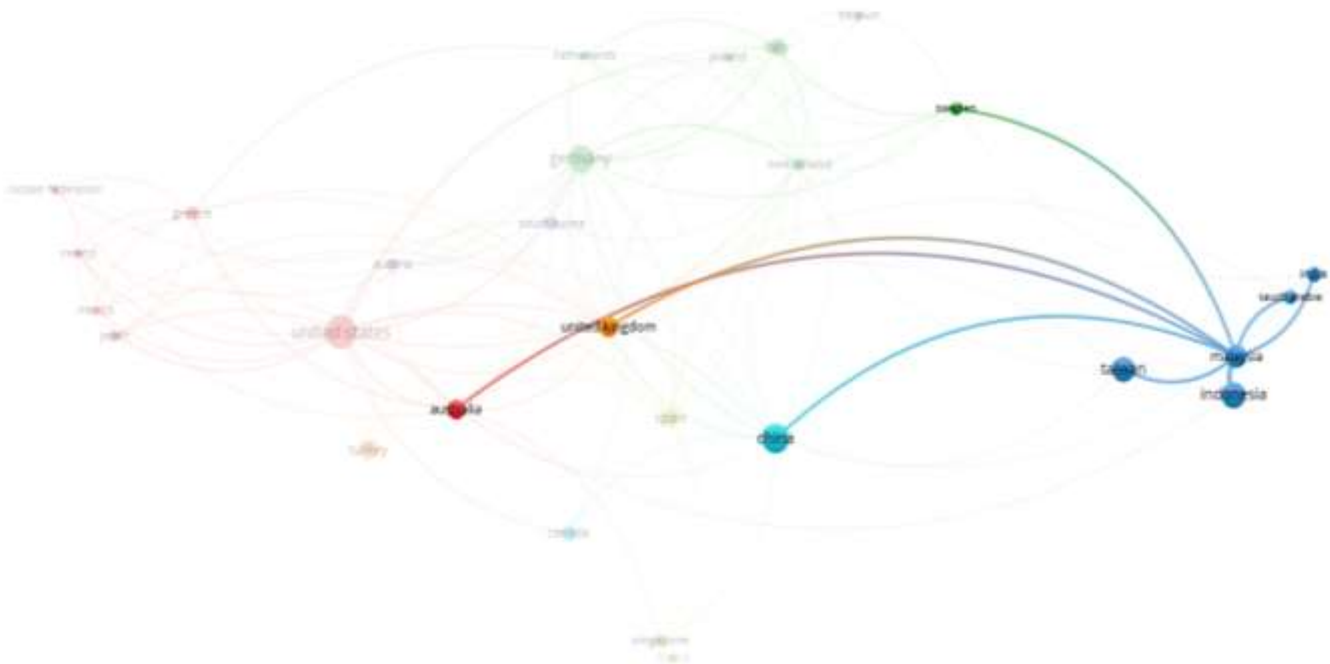

Figure 6. Network visualization cluster 3 of countries analysis

Cluster 4 includes countries such as France, Singapore, and Spain. Based on Figure 7, the most prominent country in Cluster 4 is Spain, which is connected to other clusters such as Cluster 1 (the United States and Australia), Cluster 2 (Germany, Italy, the Netherlands, Poland, Sweden, and Switzerland), Cluster 5 (Austria), and Cluster 7 (the United Kingdom). Cluster 4 is marked in yellow.

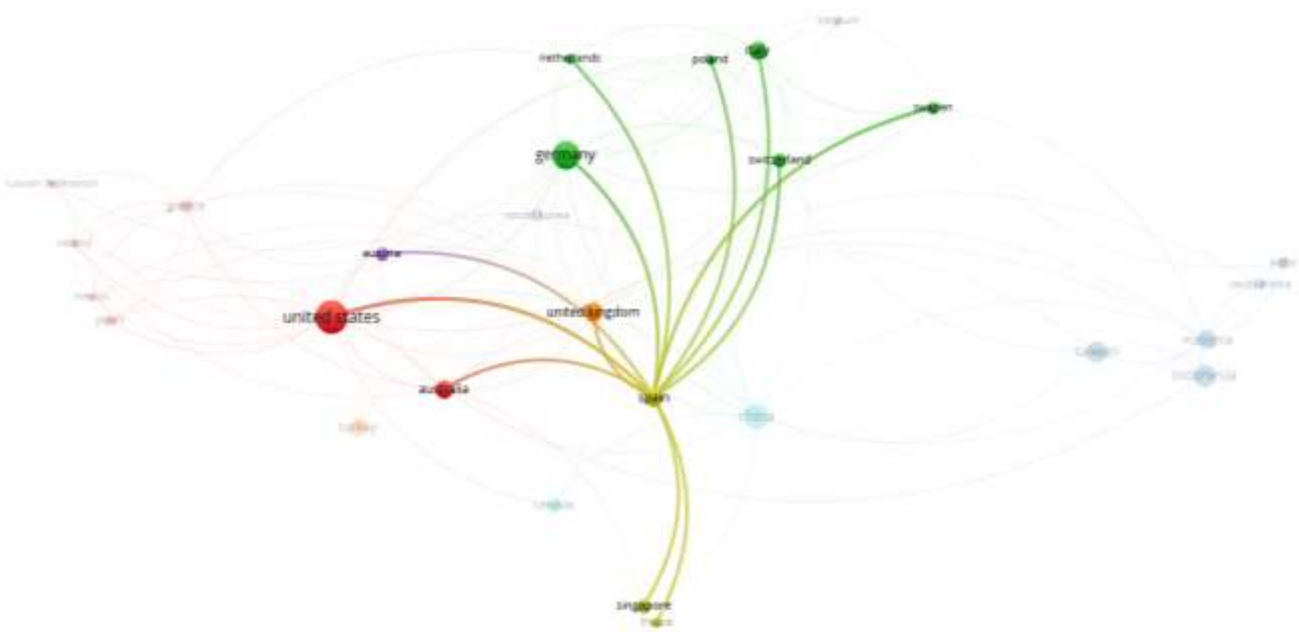

Figure 7. Network visualization Cluster 4 of countries analysis

Cluster 5 covers countries such as Austria and South Korea. Based on Figure 8, the most prominent country in Cluster 5 is South Korea, which is connected to other clusters such as Cluster 1 (the United States and Australia), Cluster 2 (Germany, Italy, and Switzerland), Cluster 6 (China), and Cluster 7 (the United Kingdom). Cluster 5 is marked with the purple color.

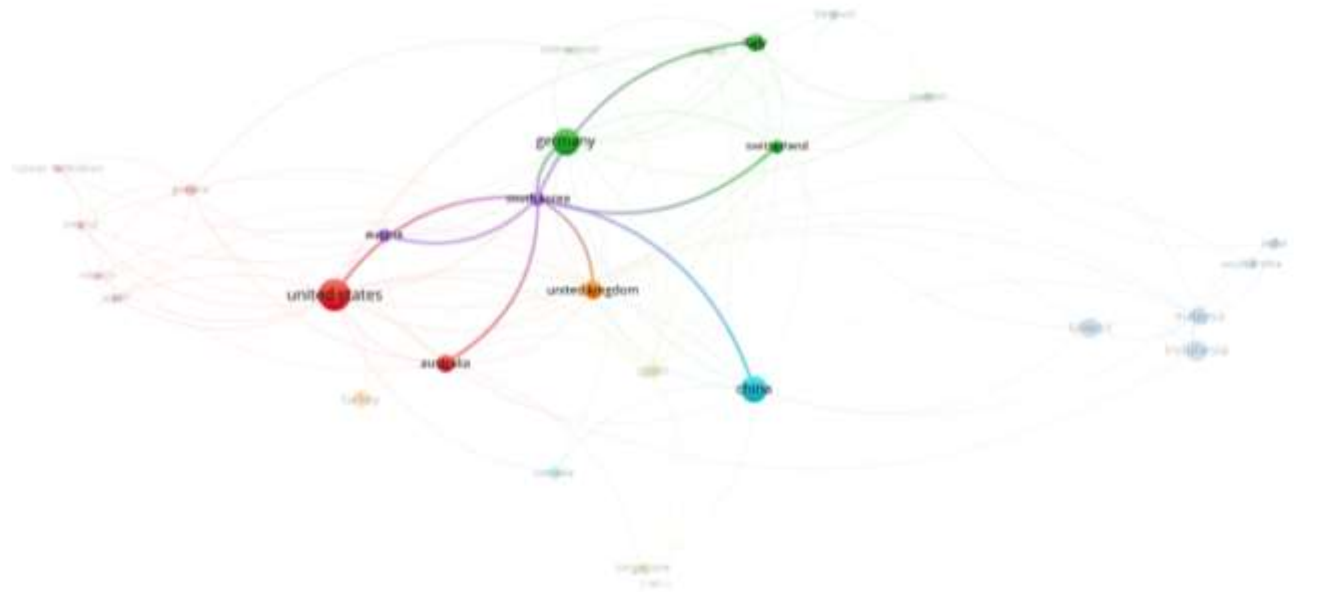

Figure 8. Network visualization Cluster 5 of countries analysis

Cluster 6 includes countries such as Canada and China. Based on Figure 9, the most prominent country in Cluster 6 is China, which is connected to other clusters such as Cluster 1 (the United States and Australia), Cluster 2 (Germany, Italy, and Switzerland), Cluster 3 (Malaysia, Saudi Arabia, and Taiwan), Cluster 4 (Singapore), Cluster 5 (Austria and South Korea), and Cluster 7 (the United Kingdom). Cluster 6 is marked with the light blue color.

Figure 9. Network visualization Cluster 6 of countries analysis

Cluster 7 includes countries such as Turkey and the United Kingdom. Based on Figure 10, the most prominent country in Cluster 7 is the United Kingdom, which is connected to other clusters such as Cluster 1 (Australia, Greece, Ireland, Japan, Mexico, and the United States), Cluster 2 (Belgium and Germany), Cluster 3 (Malaysia, Saudi Arabia, and Taiwan), Cluster 4 (Spain), Cluster 5 (South Korea), and Cluster 6 (China). Cluster 7 is marked with the orange color.

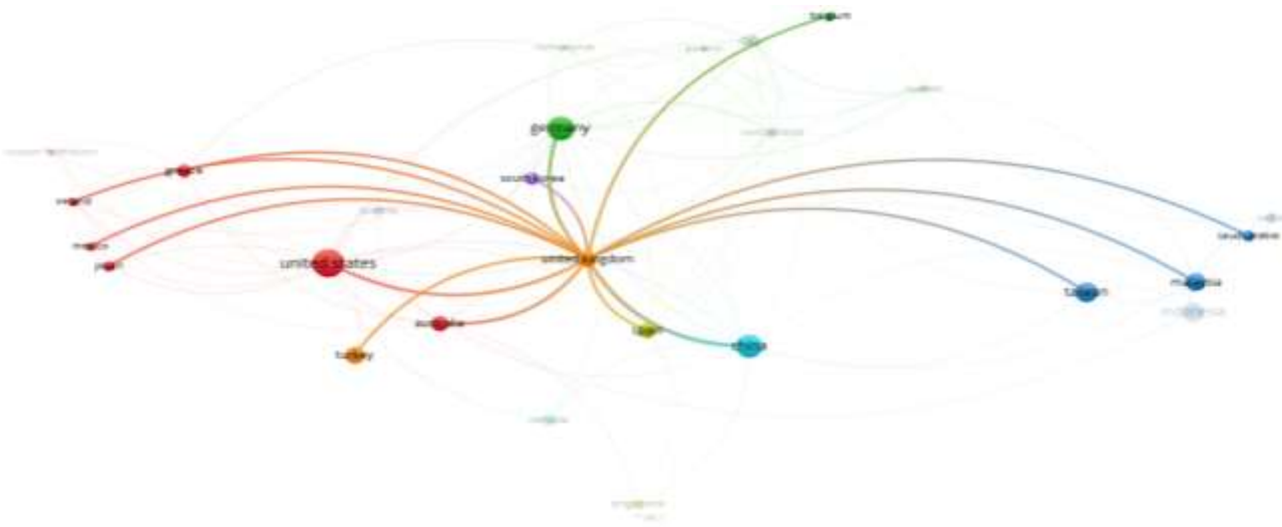

Figure 10. Network visualization Cluster 7 of countries analysis

The result of primary publications and research interests based on the author keywords in co-occurrence analysis is presented in Figure 11. Through co-occurrence analysis with a minimum number of occurrences of a keyword=5, 136 keywords were obtained.

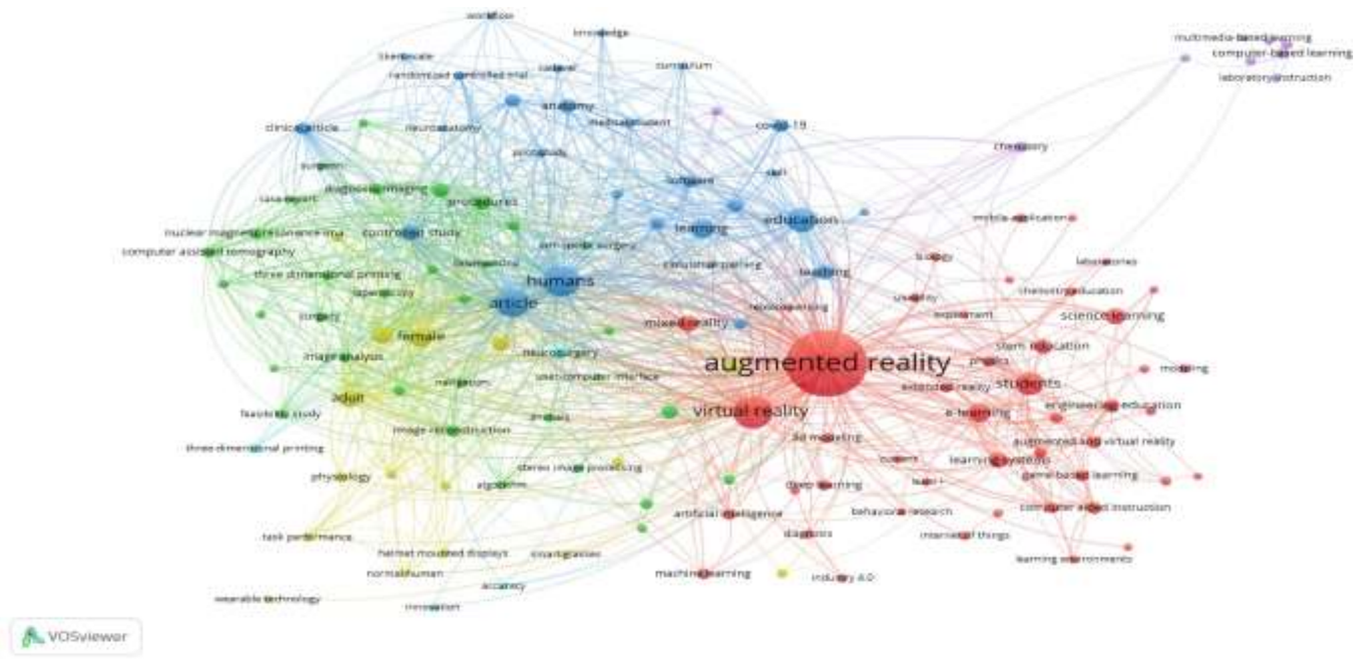

Figure 11. Network visualization augmented reality co-occurrence analysis

The VOS Viewer provides bibliometric analysis mapping with three different visualizations, namely network visualization as shown in Figure 11. These visualizations were obtained with the assistance of VOS software by extracting a total of 490 articles selected based on title, keywords, and abstracts. There are 135 identifiable items distributed across 6 clusters marked with different colors, namely red, green, blue, yellow, purple, and light blue. Each cluster represents the development of Augmented Reality research in science education, which can be observed in Table 1. The VOS Viewer offers bibliometric analysis mapping with three different visualizations, including the overlay visualization mentioned (see Figure 12). Based on Figure 12, Augmented Reality research is more related to clinical articles (Jeffers et al., 2022; Lau et al., 2023), extended reality (Chang et al., 2023; Gurses et al., 2023; Spadoni et al., 2022), likert scale (Soyka & Simons, 2022; Zatarain-Cabada et al., 2023), and nuclear magnetic resonance imaging (De Benedictis et al., 2023; Shahbaz et al., 2023). Additionally, Augmented Reality research is applied from early childhood education to higher education levels (Senduk et al., 2016). Currently, Augmented Reality research has also been presented in the form of systematic reviews (Kuswinardi et al., 2023). The results also confirm the effectiveness of bibliometric analysis (Dewi & Jauhariyah, 2021; Marlina, 2023; Rahmawati et al., 2022; Sulardja, 2021) in exploring and visualizing recent literature that can be used to decide whether further research is necessary.

Table 1. Research Development of Each Cluster

Cluster	Number of Items	Keywords
Red	47	'Current, 3d modeling, 3d visualization, artificial intelligence, augmented and visual reality, augmented reality, behavioral research, biology, chemistry education, cognitive load, computer aided instruction, deep learning, diagnosis, e-learning, education computing, engineering education, experiment, extended reality, game-based learning, gamification, higher education, improving classroom teaching, industry 4.0, internet of things, laboratories, learn+, learning environments, learning motivation, learning system, machine learning, media in education, mixed reality, mobile application, mobile learning, modeling, motivation, online learning, physics, physics learning, real-time, remote sensing, science learning, science technologies, stem education, students, usability, virtual reality.
Green	33	Algorithm, animals, case report, computer assisted surgery, computer assisted tomography, computer simulation, diagnostic imaging, feasibility study, holography, image analysis, image processing, image reconstruction, imaging, three-dimensional, laparoscopy, navigation, nuclear magnetic resonance imaging, orthopedic surgery, outcome assessment, procedures, stereo image processing, surgeon, surgery, surgical technique, surgical training, telemedicine, three-dimensional computer graphics, three-dimensional displays, three-dimensional printing, three-dimensional imaging, user-computer interface, visualization, x-ray computed tomography.
Blue	27	Anatomy, article, cadaver, clinical article, collaborative learning, controlled study, covid-19, curriculum, education, humans, knowledge, learning, likert scale, medical education, medical student, neuroanatomy, pilot study, questionnaire, randomized controlled trial, simulation, simulation training, skill, software, systematic review, teaching, training, workflow.
Yellow	16	Adult, aged, female, helmet mounted displays, human computer interaction, human experiment, male, normal human, physiology, robotics, serious games, smart glasses, task performance, technology, wearable technology, young adult.
Purple	9	Biochemistry, chemistry, computer-based learning, first-year undergraduate/general, laboratory instruction, multimedia-based learning, organic chemistry, second-year undergraduate, videorecording.
Light Blue	4	Accuracy, innovation, neurosurgery, three-dimensional printing.

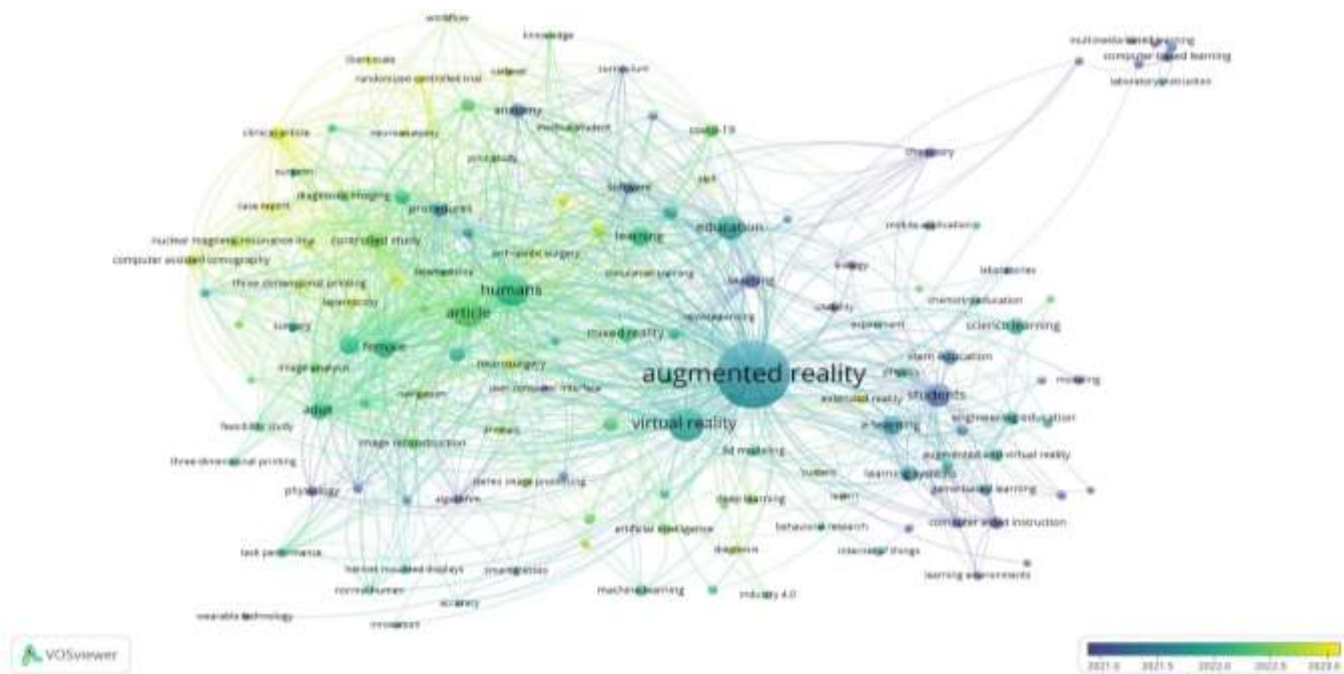

Figure 12. Overlay visualization augmented reality co-occurrence analysis

Table 2. Top 5 Author Researching Static Fluid in the Augmented Reality

Author	Title	Source Title	Cited by	Affiliations	Publisher	SJR	Quartile	Document Type
Arici et al., (2019)	Research trends in the use of augmented reality in science education: Content and bibliometric mapping analysis	Computers and Education	191	Department of Science Teaching, Kazim Karabekir Faculty of Education, Ataturk University, Erzurum, 25240, Turkey; Department of Computer Education & Instructional Technology, Kazim Karabekir Faculty of Education, Ataturk University, Erzurum, 25240, Turkey	Elsevier Ltd	1.442	Q1	Article
Fidan & Tuncel (2019)	Integrating augmented reality into problem-based learning: The effects on learning achievement and attitude in physics education	Computers and Education	172	Distance Education Research and Application Center, Bartin University, Bartin, 74100, Turkey; Faculty of Education, Department of Educational Sciences, Bolu Abant Izzet Baysal University, Bolu, 14280, Turkey	Elsevier Ltd	1.442	Q1	Article
Sahin & Yilmaz (2020)	The effect of Augmented Reality Technology on middle school students' achievements and attitudes towards science education	Computers and Education	164	Science Teacher in Republic of Turkey Ministry of National Education, Turkey; Department of Computer Education & Instructional Technology, K.K. Education Faculty, Ataturk University, Erzurum, 25240, Turkey	Elsevier Ltd	1.442	Q1	Article
Ge et al., (2019)	A bimodal soft electronic skin for tactile and touchless interaction in real time	Nature Communications	156	Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, Bautzner Landstrasse 400, Dresden, 01328, Germany; Soft Materials Lab, Linz Institute of Technology, Johannes Kepler University Linz, Altenberger Strasse 69, Linz, 4040, Austria; Soft Matter Physics, Johannes Kepler University Linz, Altenberger	Nature Publishing Group	5.116	Q1	Article

Author	Title	Source Title	Cited by	Affiliations	Publisher	SJR	Quartile	Document Type
				Strasse 69, Linz, 4040, Austria				
Thees et al., (2020)	Effects of augmented reality on learning and cognitive load in university physics laboratory courses	Computers in Human Behavior	129	Technische Universität Kaiserslautern, Physics Education Research Group, Erwin-Schrödinger-Straße 46, Kaiserslautern, 67663, Germany; German Research Center for Artificial Intelligence (DFKI), Embedded Intelligence Group, Trippstadter Straße 122, Kaiserslautern, 67663, Germany	Elsevier Ltd	0.946	Q2	Article

The type of publications used in this research is Scopus-indexed journals, and the top 5 most cited publications are obtained. The table below (Table 2) lists the 5 authors with the highest number of citations. Table 2 indicates that highly cited articles on augmented reality are dominated by Q1 quartile journals, namely Computers and Education and Nature Communications. Additionally, there are journals from the Q2 quartile, such as Computers in Human Behavior. Table 2 shows that the augmented reality topic is not only focused on specific science education but also related to the Journal of Human-Computer Studies (Heinrich et al., 2023), Journal PLOS ONE (Nakazawa et al., 2023), Journal Humanities and Social Sciences Communications (Alkhabra et al., 2023), the British Journal of Radiology (Lima et al., 2023), and Journal European Radiology (Farshad-Amacker et al., 2023).

Conclusion

Augmented Reality research grows every year. The United States provided the most significant research contribution, followed by Germany. Six clusters are visible when Augmented Reality research trends for 2019-2023 are visualized. The findings of this research can help academics look at global Augmented Reality research trends and guide future research. This analysis offers a great starting point for future Augmented Reality research.

Authors Contributions

Conceptualization; P. S & M. M., methodology; M. M., N. M., R. A., analysis; M. M., M. H. & R. A., writing—original draft preparation; M. M. & R. A. Revised: M.M. & R.A., visualization: M. H., N. M., & R. A. All authors have read and agreed to the published version of the manuscript.

Finding

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Conflicts of Interest

There are no conflicts or interests.

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