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Five years into augmented reality technology and its effects on improvement student achievement in education - A bibliometric study

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Abstract

The purpose of this study is to examine how Augmented Reality (AR) is being used to improve students' visualization skills in the field of engineering education, as well as to analyze the publication trends surrounding AR in education. In addition to an experimental study intended to assess how well AR technology enhances engineering students' visualization abilities, a bibliometric analysis of research studies on AR in education published within the last five years using the Web of Science (WOS) database was carried out. While the experimental results show that AR technology positively contributes to improving students' visualization abilities, confirming its pedagogical value as an effective teaching and learning tool, the bibliometric results show a growing trend in AR-related research within the educational field. Overall, the results show that AR's ability to close the gap between abstract ideas and visual comprehension is driving its growing adoption in education. As a useful resource for upcoming scholarly and applied advancements, this study also gives educators, researchers, and policymakers an understanding of the most significant authors and nations in the field of AR-based learning research.

Keywords: Augmented reality, Higher education, AR, Mobile learning, Education

1.Introduction

Educational technology has improved greatly in recent years, thanks to the development of new multimedia techniques and instruments aimed at improving the learning experience. Multimedia technology enhances the educational process by increasing interaction between teachers, students, and courseware, as well as developing new ways to make learning more dynamic, lasting, and applicable to the world outside the classroom (Almara'beh, Amer, & Sulieman, 2015). Augmented reality (AR) is considered as interactive multimedia technology which has shown potential as a teaching and learning tool in education. AR provides learners with an immersive and interactive experience by combining real-world and virtual components (Arici et al., 2019). Sabbah et., al. (Sabbah, Mahamid, & Mousa, 2023) argued that emerging technologies have a considerable impact on education, one of which is extended Reality XR (Augmented Reality/Virtual Reality/Mixed Reality). (Sabbah, Mahamid, & Mousa, 2023) AR clearly has the potential to aid learning and teaching, in their study Akçayır and Akçayır (2017) conclude that augmented reality technology may increase students' learning performance, and that academic achievement has received a lot of attention in AR research. Other learning outcomes, such as satisfaction and confidence, have received less attention, despite their importance in educational contexts (Akçayır & Akçayır, 2017; Masih et al., 2025).

The growing amount of research on the use of augmented reality in education has covered a wide range of topics, including preparing instructors to utilize augmented reality (Diao & Shih, 2019), student attitudes toward augmented reality, and the effect of augmented reality on learning outcomes (Alqarni, 2021). In Education AR bridges the gap between reality and virtual reality by employing hybrid modes of learning such as graphic design, visualization, and simulation. By enhancing the learning content, cooperating, synthesizing, and imagining phenomena, the forms assist knowledge of the real world and existing phenomena (Ropawandi, Halim, & Husnin, 2023). Mystakidis et., al. (Mystakidis, Christopoulos, & Pellas, 2022)stated that AR has certain distinct benefits that, individually and collectively, increase motivation, increase incentives for engagement, and hence facilitate achievement of

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learning objectives. AR will play an essential role in education in the future since it can boost student achievement (Ropawandi, Halim, & Husnin, 2023).

This bibliometric study aims to provide a comprehensive and up-to-date analysis of the multifaceted landscape surrounding augmented reality (AR) technology and its impact on improving student achievement in the realm of education. This study seeks to illuminate the intricate interplay between AR adoption and its impact on student outcomes by delving into a plethora of scholarly works published over a five-year period. The investigation will specifically include a thorough examination of variables such as the volume of research conducted, geographical distribution, temporal trends, and thematic areas of focus. This study aims to shed light on the potential benefits and challenges of integrating AR technology into education by distilling and synthesizing the wealth of knowledge present in the literature, while also paving the way for future research.

2. Statement of the problem

The integration of Augmented Reality (AR) technology in education holds the promise of revolutionizing teaching and learning experiences. Over the past 10 years (Elnaqlah, 2023). AR studies may be conducted in more courses from various countries or nations in the future, given that 3D models in AR may be effective for other topic materials with abstract notions (Ropawandi, Halim, & Husnin, 2023). The study by Mystakidis et al. concludes that augmented reality (AR) has the potential to improve STEM education and highlights the lack of research utilizing AR across the Science, Technology, Engineering, and Mathematics (STEM) spectrum. They contended that additional research is required to address the identified gaps and challenges, which can include studies in the element of technology and engineering in a STEM context (Mystakidis, Christopoulos, & Pellas, 2022). Badilla-Quintana et., al. stated that educators must understand how to improve their effectiveness in action, to rethink education and create new ways of teaching and learning in order to improve not just their students' academic achievement, via the development of effective learning experiences (Badilla-Quintana, Sepulveda-Valenzuela, & Salazar Arias, 2020). In the same way Comparative studies are required so that it may be held by examining students' attitudes, achievement, and cognitive loads for AR applications in many domains of education (Küçük, Yýlmaz, & Göktaþ, 2014).

3. Research questions

The following are the research questions presented in this study, all of which are related to entries in the 'Scopus' online literature source:

RQ 01: What is the distribution of publications over the earlier 5 years by year that employ AR to improve student achievement?

RQ 02: What is the most common subject area where the use of AR to increase student achievement is being researched?

RQ 03: What is the distribution of the most often used words in the titles and abstracts of articles on the use of AR to increase student achievement?

RQ 04: Who are the most cited (citation and co-citation) authors in articles on use of AR to increase student achievement?

RQ 05: Which are the most cited journals publishing articles on the use of AR to increase student achievement?

RQ 06: What are the top organizations or affiliations that have made the most contributions to the field of Augmented Reality (AR) to improve student achievement through their publications?

RQ 07: Which nations exhibit the highest effectiveness in utilizing Augmented Reality applications to enhance student achievement?

4. Methodology

This study aims to highlight the profile of research conducted over the previous five years to improve student achievement by incorporating Augmented Reality into the teaching process. To achieve this goal, the study combined bibliometric and visualization tools. Furthermore, bibliometric analysis focuses on tracking research on a specific topic and exposing the conclusions by evaluating these studies based on a variety of criteria.

With regard to Mongeon and Paul-Hus (Mongeon & Paul-Hus, 2016) argued that Bibliometric analysis findings may differ based on the database utilized. Equally important to know that Web of Science and Scopus appear to be the two most comprehensive databases (Chadegani et al., 2013). However, Mongeon and Paul-Hus (Mongeon & Paul-Hus, 2016) stated that Scopus database has the largest coverage in the fields of Sciences and Engineering, Social Sciences and Arts, and Humanities. In the same way Baas et., al (Baas et al., 2020; Fatima et al., 2025) pointed out that Scopus' trustworthiness has led to its adoption as a bibliometric data source for large-scale analysis in research evaluations, research landscape studies, scientific policy evaluations, and institution rankings. Scopus database was used as the literature source for the bibliometric mapping study, the search was conducted on July 28, 2023. The keywords used for content analysis were not related to the title. The keywords provided into the advanced search feature were
"students" AND "achievement" AND "augmented" A
ND "reality" AND "education".

Some limitation was added to the search. For the purpose of quality and dependability; search limited to Journals because journals typically employ a peer-review procedure in which experts in the area assess the study before it is published Kelly et., al (Kelly, Sadeghieh, & Adeli, 2014). In the same way and for availability of detailed data like methodology, validity, participant and results, the search string was restricted to Article.

Finally, for global reach and accessibility reason the search limited the language to English, A total of 90 published articles employs AR in education in general to measure improvement of student achievement were accessed. Then, full records and cited references were downloaded in Export option with (.CSV) file format.

The file was imported into the VOSViewer application. VOSviewer can analyze many types of bibliometric network data, such as citation relationships between publications or journals, cooperation relationships between researchers, and co-occurrence links between scientific words (Van Eck & Waltman, 2011). *Figure 1* summarizes the article selection procedure for this study.

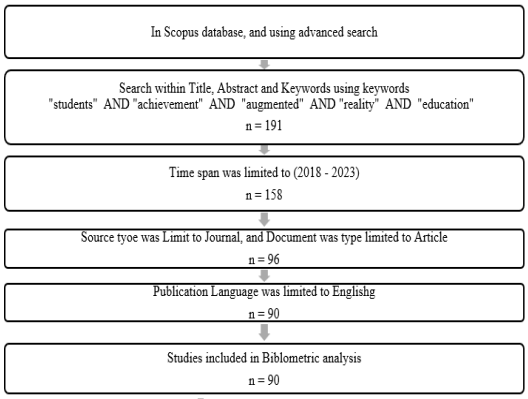

Figure 1: study's article selection procedure

5. Findings

5.1 Distribution of AR s

To address the first finding, a study of the publication year of publications during the previous five years was conducted. Whereas 2023 had the most published research papers with a total of 19 research connected to the utilization of augmented reality to increase student accomplishment, followed by and 2021 that had a total of 19 researches. 2022 had a total of 17 research. With a total of seven research papers, 2018 was the year with the fewest publications linked to the use of augmented reality to increase student attainment. *Figure 2* shows how the publications were distributed over the years.

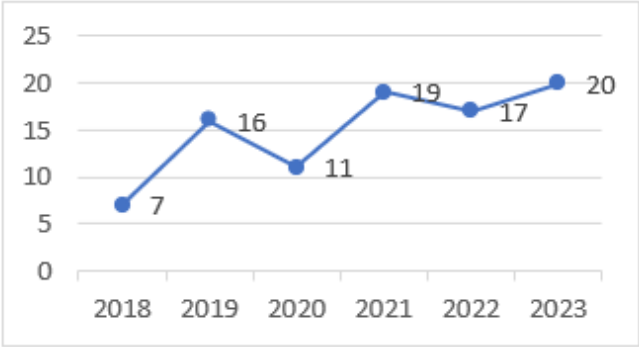

Figure 1: Articles by year

5.2. The most common subject area where the use of AR to increase student achievement is being researched

An in-depth review of publications across several subject areas during the last five years was done to answer this research question in detail. According to

the findings, the field of social sciences had the most research papers published, totaling 73, followed by computer science, totaling 54, all of which focused on the use of augmented reality technology to improve student achievement. Engineering was close behind with 11 research publications dedicated to the subject, while psychology provided 6 research papers. *Figure 3* shows the overall number of publications in these additional subject areas, offering light on their relative contributions to the research of augmented reality in education and its impact on student results.

The research highlights the multidisciplinary nature of augmented reality's application in various fields, including social sciences, computer science, engineering, and psychology, highlighting its potential in learning outcomes and cognitive development.

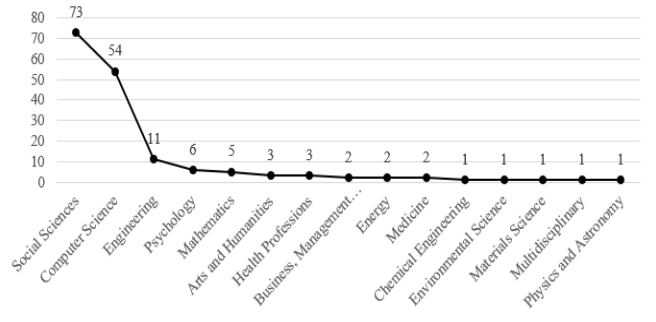

Figure 03: Articles by subject area

5.3 Most used keywords in the articles related to use of AR apps to increase student achievement

Co-occurrence analysis and author keywords were utilized to construct a map based on text data for the most commonly used keywords. The minimum number of keyword occurrences was set to 5, and the number of keywords to be selected was automatically set to 16. *Figure 4* depicts the final version of the map. There are two clusters, and the most often used keyword is 'augmented reality' (*f*=26). Furthermore, the most often used keywords are 'students' (*f*=22), 'e-learning' (*f*=14), 'computer aided instruction' (*f*=11), and 'learning systems' (*f*=11). These findings indicate that the publications mostly address augmented reality and its application in teaching and learning e-environments. It can be shown that the number of AR studies in enhancing student achievement began to increase in 2020. When the quantity of papers containing the keywords is distributed by year, it is clear that current articles are mostly concerned with improving classroom teaching.

The research on AR applications in education highlights the importance of augmented reality, student-centered learning, technology integration, and innovative instructional methods. The surge in AR-related studies since 2020 demonstrates the potential of AR technology and the evolving research interests in enhancing student outcomes.

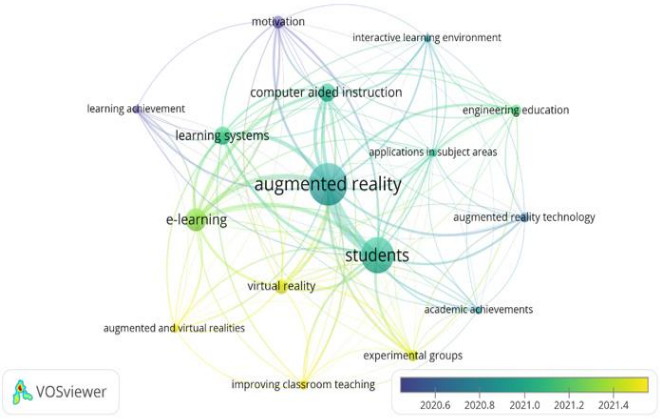

Figure 2: Most used keywords found in the titles and abstracts

As shown in *Table 1*, the analytic criteria for the prolific authors in the study area of employing Augmented reality applications to increase student achievement were "Author," "Year of 1st publication," "Total Publications," "h-index," "Total citations," "current affiliation," "country," and "Author ID".

Table 1 lists 10 prominent authors in the field of augmented reality (AR) application and student achievement. In addition, the most prolific author was “Hwang, Gwojen” with total of 533 publication, with the highest h-index 73 and a total citation of 11418, the author from Taiwan and currently working at National Taiwan University of Science and Technology. Followed by “Kazanidis, Ioannis K.” with total of 78 publication, with the h-index 15 and a total citation of 743, the author from Greece and currently working at International Hellenic University. Following that “Pellas, Nikolaos” with total of 51 publication, and with the h-index 17, a total of 923 citation, the author also from Greece and currently

working at University of Western Macedonia.

More interestingly, the top three h-index authors are the same, but in a different order: "Hwang, Gwojen" has the highest index, followed by "Pellas, Nikolaos" and, finally, "Kazanidis, Ioannis K.". Other productive authors in the subject of study are also included in *Table 1*.

Furthermore, co-citation analysis and cited authors were chosen. The minimum number of citations of an author was set at 30, and the number of authors to be chosen was set to 17. *Figure 5* depicts the map that was developed. It demonstrates that the most cited (co-cited) authors in this field are hwang g.j. (71 citations), ibanez m.b. (62 citations), and yilmaz r.m. (58 citations).

Figure 6 shows the productivity charts of the 14 most productive authors in terms of employing Augmented Reality applications to improve achievement among students. With three papers, "Pellas, N." has the most publications in the field of study on the use of Augmented Reality applications to increase achievement among students. Following that are 13 authors, “Abdullah, N.”, “Arici, F.”(Arici et al., 2019), “Cakmak, E.K.”, “Chen, C.H.”, “Christopoulos, A.”, “Hwang, G.J.”, “Kazanidis, I.”, “Liu, Y.C.”, “Lu, S.J.”, “Sirakaya, M.”, “Turan, Z.”, “Yildirim, P.”, “Yilmaz, R.M.”, all of them have two publications in this topic, and the remaining authors have only one.

Figure 3: Most cited authors (Co-citation analysis).

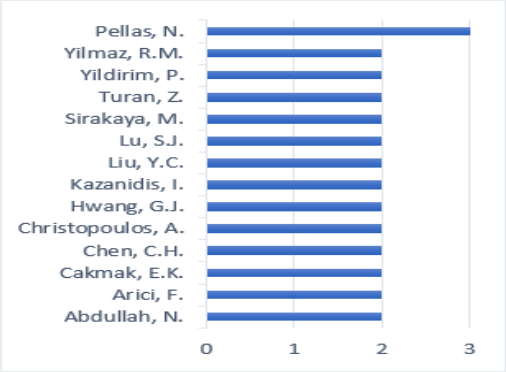

Figure 4: A list of the 14 most productive authors regarding using AR to improve students’ achievements

Table 1: A list of the 10 most productive authors in the field of AR research and student achievements

No	Author	Year of 1st publication	TP	H-index	TC	Affiliation	country	Author ID
1	Pellas, Nikolaos	2013	51	17	923	University of Western Macedonia	Greece	5.59E+10
2	Abdullah, Norazilawati Binti	2018	15	5	42	*Universiti Pendidikan Sultan Idris*	Malaysia	5.72E+10
3	Arıcı, Faruk	2019	5	4	200	Republic of Turkey Ministry of National Education	Turkey	5.72E+10
4	Kılıç Çakmak, Ebru	2008	19	8	291	Gazi University	Turkey	3.65E+10
5	Chen, Chih-Hung	2012	19	11	594	National Taichung University of Education	Taiwan	5.62E+10
6		2012	39	9	289	University of Turku	Finland	5.55E+10

	Christopoulos, Athanasios							
7	Hwang, Gwojen	1990	533	73	11418	National Taiwan University of Science and Technology	Taiwan	7.2E+09
8	Kazanidis, Ioannis K.	2007	78	15	743	International Hellenic University	Greece	2.4E+10
9	Liu, Yingchieh	1999	33	9	453	Chang Gung University	Taiwan	3.58E+10
10	Lu, Suju	2009	19	4	195	National Taipei University of Education	Taiwan	3.58E+10

5.5. Most cited journals

Table 2shows the data extracted from Scopus database that indicates the top 10 most productive journals on students' achievements AR apps over the last 5 years, The analytic criteria for the most cited journals were "Total Publication," "Total Citation," "Cite Score of the journal," "The Most Cited Article in the last 5 years," "Times Cited," and "Publisher," as shown. It can be noticed that the most cited journals are Computers &Education (780 citations, 9 documents), Interactive Learning Environments (664 citations, 8 documents) and Education and Information Technologies (536 citations, 3 documents).

5.6 The top organizations or affiliations that have made the most contributions to the field of study.

Figure 7 offers valuable insights into the landscape of AR research and its impact on student achievement, the total affiliations was 134 that have publications in this field, 13 of them have published two articles and 114 have only one article in that field. as the educational institution with the highest publication of research related to the studied field is "Atatürk Üniversitesi" with a record publication count of 6 publications, emerges as the leader in this research arena, highlighting its important contribution to furthering understanding of AR's impact on enhancing student outcomes, followed by "National Taiwan University of Science and Technology" with 5 publications, and in the next level "Universiti Sains Malaysia", "Gazi Üniversitesi", "National Taichung University of Education", "National Taipei University of Education" and "Universiti Pendidikan Sultan Idris" with 3 publications each. This distributed participation demonstrates the global interest and collaboration in leveraging the capabilities of augmented reality to improve student accomplishment.

In summary *Figure 7* shows various affiliations contributing to AR research for student achievement. Institutions' prominence reflects their commitment to pushing boundaries, paving the way for informed and impactful integration of AR in educational settings for improved learning outcomes.

Table 2: The Top 10 most productive journals on students' achievements ar applications over the last 5 years

Journal	TP	TC	Cite score	The most cited article	Times Cited	Publisher
Computers and Education	791	18818	23.8	A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda	780	Elsevier
Interactive Learning Environments	370	4054	11.0	Covid-19 pandemic and online learning: the challenges and opportunities	664	taylor and francis online

Journal	TP	TC	Cite score	The most cited article	Times Cited	Publisher
British Journal of Educational Technology	533	7381	13.8	A systematic review of research on the flipped learning method in engineering education	244	British Journal of Educational Technology
Education Sciences	2390	4983	4.0	E-learning critical success factors during the covid-19 pandemic: A comprehensive analysis of e-learning managerial perspectives	234	Education Sciences
International Journal of Information and Education Technology	599	1216	2.0	Leveraging Digital Technology for Better Learning and Education: A Systematic Literature Review	42	International Journal of Information and Education Technology
Cypriot Journal of Educational Sciences	480	415	1.1	Understanding patterns for smartphone addiction: Age, sleep duration, social network use and fear of missing out	45	Cypriot Journal of Educational Sciences
Education and Information Technologies	1298	10614	8.2	A review of the use of virtual reality head-mounted displays in education and training	536	Springer Nature
Eurasian Journal of Educational Research	294	648	2.2	The effect of augmented reality applications in the learning process: A meta-analysis study	79	ANI Publishing
International Journal of Emerging Technologies in Learning	1683	8389	5.0	Big data emerging technology: Insights into innovative environment for online learning resources	172	International Journal of Emerging Technologies in Learning (iJET),
Journal of Computer Assisted Learning	372	2982	8.0	Motivational and cognitive benefits of training in immersive virtual reality based on multiple assessments	171	Wiley - Journal of Computer Assisted Learning

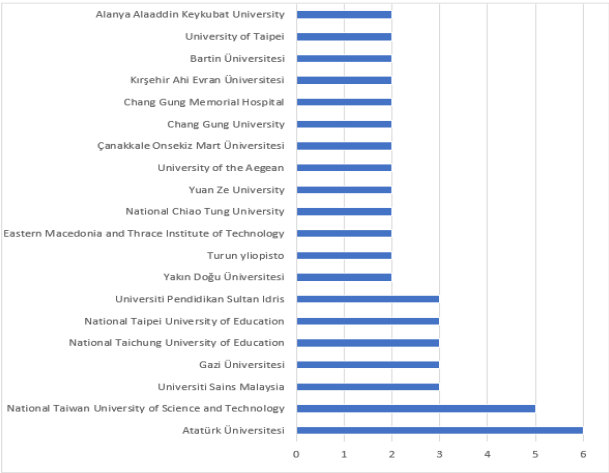

Figure 7: Affiliation distribution in augmented reality (AR) and its effect on students' achievement research

5.7 The countries exhibit the highest effectiveness in utilizing AR apps to enhance student achievement

Using Scopus database analysis feature, *Figure 8* shows the list of countries that have contributed in the field of using Augmented reality applications to enhance students' achievement.

For the most prolific nations *Table 4* shows only the top five countries in this field have been listed because the nations that follow these five are institutions where researchers have only ever produced one article for each, it is therefore difficult to identify an institution with the greatest publishing ranking.

Turkey appears as the frontrunner among the top five most prolific nations in this subject, with a total of 23 publications. The most prolific academic institution in this context is Turkey's Atatürk Üniversitesi, which contributed 7 articles. Taiwan comes close behind, with 16 publications in this field, led by the National Taiwan University of Science and Technology, which contributed four pieces. China tie for third place, providing eight publications. Yuan Ze University in China with two articles. Followed by Malaysia providing seven publications in the fourth place, with three articles each Universiti Sains Malaysia, and Universiti Pendidikan Sultan Idris in Malaysia are at the forefront of these contributions. Greece is ranked fifth with a total of six publications, Eastern Macedonia and Thrace Institute of Technology and the University of the Aegean both contributed two publications. These countries' prolific production demonstrates the global interest and commitment to expanding the integration of AR applications to improve student accomplishment.

Co-authorship analyses and countries were chosen in order to build a map for the majority of co-authorship countries. A source's minimum number of documents was set at 5, while its minimum number of citations was set at 10. The number of sources to be chosen was automatically set to six. The resulting map is displayed in *Figure 9*. It clear that the research environment is diversified and collaborative. The analysis found three distinct groups of countries, each with shared research objectives and patterns of collaboration. Taiwan emerges as a key participant, leading the first cluster, which includes China and Malaysia. This shows that this group has a robust scientific collaboration and knowledge exchange. Meanwhile, Greece stands out as a one-of-a-kind contributor, potentially engaged in research areas that are less connected to the other countries. Finally, the United Kingdom forms a unique cluster, indicating its importance in the research network. The total strength of 6 suggests that the nations in the sample have a moderate level of collaboration and connectivity. These findings underline the relevance of international research relationships in the field and provide chances for nations within the same cluster to strengthen cooperation and partnership.

However, in order to acquire a thorough knowledge of the collaborative landscape and to drive future research initiatives and international alliances, these findings must be contextualized, taking into account aspects such as geopolitical dynamics, research priority areas, and historical linkages.

Table 3: List of the 5 most prolific countries in the research area of using AR apps to improve students' achievements

Rank	Country	TP	Most prolific Academic Institution	No. of articles
1	Turkey	23	Atatürk Universitas	7
2	Taiwan	16	National Taiwan University of Science and Technology	4
3	China	8	Yuan Ze University	2
4	Malaysia	7	Universiti Sains Malaysia	3
			Universiti Pendidikan Sultan Idris	3
5	Greece	6	Eastern Macedonia and Thrace Institute of Technology	2
			University of the Aegean	2

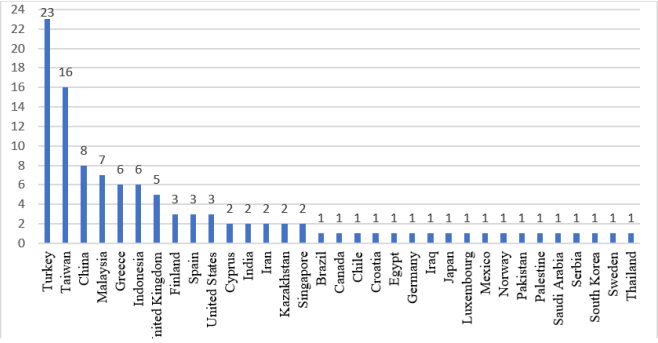

Figure 8: A list of the countries has publications regarding using AR to improve students' achievements

Figure 5: Analysis results of prolific countries (co-authorship) of the research that use AR Apps to improve students' achievement

6.Discussion

The SLR articles under discussion here use experimental and quasi-experimental research designs to compare at least two groups—one using conventional teaching and learning methods and the other using an AR application—in order to examine the efficacy of AR applications in higher education.

AR has been discovered to be especially helpful in the engineering and health sectors. While Kwiatek et al. (Kwiatek et al., 2019) discovered that AR can significantly speed up pipe spool assembly compared to traditional methods, Bork et al. (Bork et al., 2021) and Ali et al. (Ali et al., 2017) noted that AR applications can help students better understand complex 3D structures that are challenging to represent in real or fake models. Additionally, AR applications have been reported to improve students' laboratory skills by Akçayir et al. (Akçayır et al., 2016), Kurt & ÖZtürk (Kurt & Öztürk, 2021), and Mladenovic et al. [17]. In their 2016 study on the impact of AR on cognitive load, Küçük et al. (Küçük, Kapakin, & Göktaş, 2016) discovered that the group using AR had higher achievement and less cognitive load. In addition, several studies (Gutiérrez & Fernández (Gutiérrez & Fernández, 2014); Lee et al., (Lee et al., 2013)) noted the learners' positive attitudes toward the use of AR in learning and teaching, as well as their increased engagement and motivation. Overall, the majority of studies discovered that experimental students who used augmented reality (AR) applications outperformed their peers who used conventional teaching and learning techniques. Positive effects on students' knowledge and skill levels have been reported by Christopoulos et al. (Christopoulos et al., 2022), Nordin, Nordin, & Omar (Nordin, Nordin, & Omar, 2022), Kurt & ztürk (Kurt & Öztürk, 2021), and Martin-Gutierrez (Martín-Gutiérrez, 2011).

Only Herbert et al.'s study from 2021 (Herbert et al., 2021) found no significant distinctions between experimental and control groups in terms of learning, but the results show that students preferred the AR app.

These results indicate that AR applications can significantly enhance learning outcomes, engagement, and motivation in higher education, especially in disciplines like engineering and health. To fully understand the advantages and restrictions of using augmented reality in education, more research is required.

7.Conclusion

In conclusion, the systematic literature review has explored the use of Augmented Reality (AR) applications in higher education, and the impact of AR on student satisfaction, acceptance, and achievement. The review has synthesized the evidence from a number of studies, and has provided a comprehensive understanding of the use of AR in higher education.

The findings of the review suggest that AR technology has the potential to positively impact student satisfaction, acceptance, and achievement in higher education. The use of AR technology can enhance the learning experience and increase student engagement, leading to improved outcomes in higher education.

However, the systematic literature review has also highlighted some limitations and challenges associated with the use of AR in higher education. The quality of the studies included in the review can vary

greatly, and the selection of studies for inclusion can be subject to bias. Additionally, the findings from the review may not be generalizable to other populations or settings, as the studies included in the review may be limited to a specific population or geographical location.

Despite these limitations, the systematic literature review provides valuable insights into the use of AR in higher education, and the impact of AR on student satisfaction, acceptance, and achievement. The review highlights the potential benefits of AR technology for higher education, and provides a foundation for future research on this topic.

8.Limitations

While this bibliometric analysis provides useful insights into the trends and patterns around the use of augmented reality technology in improving student achievement over the last five years, it is important to recognize its limits. At first, the Scopus database was only used to collect statistics. As a result, it does not cover all academic articles, and publications from other databases such as "Web of Science" may not have been included in this study. Second, the study only uses data taken from academic databases, potentially eliminating conference papers and non-English publications that could contribute to a thorough understanding of the topic. Third, the bibliometric analysis may miss qualitative features of the included papers, such as methodology used, research quality, and nuances in their findings.

Furthermore, the study's emphasis on publication data may not fully convey the actual consequences of augmented reality technology's impact on student achievement, as it ignores obstacles, implementations, and real-world outcomes. Finally, bibliometric studies inherently possess a degree of subjectivity in terms of keyword selection, search strategies, and data interpretation, which may influence the representation of specific subfields or research issues.

It is critical for readers and researchers to realize these limitations when interpreting the study's findings and to use them as triggers for more in-depth investigations into the many facets of augmented reality's involvement in education.

Contributions of the authors

The study was conceived by Abdullah Ahmed ElNaqlah, who also created the research framework, carried out the experimental and bibliometric analysis, and wrote the first draft of the manuscript.

The research process was overseen by Nurullizam Jamiat, who also reviewed and improved the final manuscript, offered insightful criticism on the study design and analysis, and helped interpret the findings. The final draft of the paper was read and approved by both authors.

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