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Augmented Reality in Elementary School: A Bibliometric Analysis of Research Trends and Development

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Abstract. This study aims to map the development, productivity, and research trends related to the use of Augmented Reality (AR) in elementary education over the past two decades through a bibliometric approach. Data were retrieved from the Scopus database using the keywords "augmented reality," "primary school," and "elementary school," and filtered through inclusion–exclusion criteria and the PRISMA procedure. A total of 206 articles met the eligibility criteria and were analyzed using VOSviewer and Biblioshiny. The results show a substantial increase in AR related publications in primary education, particularly since 2019, indicating a period of rapid groeth. Taiwan is the most productive and influential country, followed by Malaysia and Indonesia. Leading educational technology journals, including Computers & Education and Educational Technology & Society, play a major role in disseminating AR research. Keyword analysis reveals three dominant themes: AR integration in mathematics and science learning; challenges and teacher readiness for AR implementation; and the development of interactive AR–VR-based learning environments. Recent studies increasingly focus on pedagogical effectiveness, cognitive load, learning motivation, and mobile learning. Overall, AR demonstrates considerable potential to improve students' conceptual understanding, motivation, and learning experiences despite ongoing technical and pedagogical challenges. These findings provide insight for policymakers, educators, and researchers seeking to advance AR integration in primary education.

Keywords: Augmented reality; Bibliometric analysis; Educational technology; Elementary school; Research trends

1. Introduction

Due to the quick development of information and communication technology and the growing need for 21st-century skills, digital transformation has significantly changed elementary education around the world. In addition to raising academic performance, schools are supposed to promote critical thinking, creativity, teamwork, and digital literacy. Following the COVID-19 pandemic, which brought attention to the significance of technology-enhanced learning environments capable of supporting meaningful and flexible learning experiences, the integration of digital technologies into primary education has accelerated in recent years (Bond et al., 2021; UNESCO, 2023). As a result, educators and legislators are looking more and more into cutting-edge digital solutions that can support experiential and student-centered learning.

Immersion technologies like Virtual Reality (VR), Mixed Reality (MR), and Augmented Reality (AR) have garnered a lot of attention among new educational technologies due to their capacity to produce dynamic and captivating learning environments. By integrating digital content with the real world in real time, augmented reality (AR) enables learners to interact simultaneously with physical and virtual objects, creating interactive and contextualized learning experiences (Godoy, 2020; Koumpouros, 2024). According to Piaget's theory of cognitive development (Cheng & Tsai, 2013; Piaget, 1970), elementary school students are in the concrete operational stage and comprehend concepts better when they are presented in visual and manipulable forms rather than abstract representations. This trait is consistent with this theory. AR offers the ability to connect abstract ideas with real-world learning experiences through various affordances.

Recent years have seen a significant increase in research on augmented reality in education, showing its beneficial effects on academic success, motivation, memory retention, and learner engagement (Donthu et al., 2021; Tomaszewski, 2023; van Eck & Waltman, 2010). Additionally, AR facilitates constructivist learning settings where students actively create knowledge through interaction and inquiry. Existing reviews have mostly concentrated on learning efficacy, certain subject domains, or short-term implementation outcomes despite the increasing number of studies. Comprehensive mapping of the intellectual structure, publishing trends, key contributors, and emerging issues of AR research in primary education from a global viewpoint has received little attention.

A bibliometric analysis is required to methodically investigate the advancement, output, and future directions of AR research in primary education in order to close this gap. This study attempts to give a thorough overview of the current status of AR research and suggest possible directions for further research by examining publishing patterns, collaboration networks, and theme evolution during the previous 20 years. The results are anticipated to support instructional innovation, evidence-based policymaking, and the successful use of immersive technologies into primary education.

1.1. Problem Statement

Even though there is an increasing amount of data demonstrating Augmented Reality's (AR) educational advantages, research on the technology's efficacy is still uneven. While many studies show that augmented reality (AR) improves students' learning outcomes, motivation, and engagement, other studies show that the effectiveness varies depending on the educational setting and learning conditions (Buchner et al., 2022; H. Y. Chang et al., 2022). This discrepancy shows that our knowledge of AR application in elementary education is still incomplete and needs more research.

These differences could be caused by a number of things. Subject domains, educational environments, student characteristics, and instructional design all seem to have an impact on how effective AR is (Buchner et al., 2022; H. Y. Chang et al., 2022) . Furthermore, the successful integration of AR into real-world classroom practices is still hampered by practical obstacles like usability problems, technical constraints, cognitive overload, inadequate teacher preparation, and poorly developed pedagogical designs (Bacca et al., 2014a; Garzón & Acevedo, 2019; Gonnermann-Müller & Krüger, 2025; Zekeik et al., 2025). These difficulties might limit AR's scalability, sustainability, and wider use in elementary education.

While AR in education has been the subject of many systematic reviews and meta-analyses, the majority of these studies concentrate on quantifying its impact on learning outcomes. Examining publishing trends, collaborative networks, significant contributors, and theme advancements within AR research in primary education has received little attention. The identification of research gaps, emerging themes, and future research orientations that are sensitive to the developmental traits and learning requirements of primary school kids is hampered by the lack of such thorough mapping. For a comprehensive knowledge of the development and philosophical framework of AR research in primary education, a bibliometric analysis is therefore required.

1.2. Related Research

The application of augmented reality (AR) in educational settings has been the subject of several recent research. For example, Chang et al. (2022) found that AR has a favorable impact on students' learning outcomes, especially conceptual understanding, learning motivation, and engagement, based on a meta-analysis of research done over the past ten years. Similarly, in a systematic study, Buchner et al. (2022) noted that augmented reality (AR) can improve learning performance and lessen cognitive load, while its efficacy varies depending on learner characteristics, educational situations, and instructional design. Additionally, Singh et al. (2024) highlighted that augmented reality (AR) has developed beyond a visualization tool and is being used more and more to facilitate interactive, collaborative, and experiential learning settings.

Despite these contributions, the majority of studies that are now available mostly concentrate on assessing the efficacy and use of augmented reality in educational settings, offering little insight into the conceptual framework and developmental trends of this field's study. While immersive technologies in education have been the subject of various bibliometric research, these studies often have a broad focus and infrequently address the particular context of elementary education (Tlili et al., 2022). As a result, bibliometric studies that precisely track the evolution, collaboration patterns, and thematic progression of AR research in elementary education remain severely lacking.

The present study's originality in addressing this gap is its bibliometric analysis, which focuses solely on AR literature in primary school. This study uses a Scopus-based bibliometric approach visualized through VOSviewer to examine publication trends, scientific collaboration networks, influential contributors, and the evolution of research themes, in contrast to earlier studies that primarily focus on learning outcomes and implementation effectiveness. It is anticipated that this method will offer a more thorough knowledge of the evolution and potential paths of AR research in elementary education.

1.3. Research Objectives

Based on the background and the identified research gaps, this study aims to conduct a bibliometric analysis of the literature on the use of Augmented Reality (AR) in primary education. Specifically, this study seeks to mapping the number of AR publications and citations in elementary school.

1. map the number of publications and citations related to AR in primary schools;
2. identify key actors, including the most influential authors, institutions, and countries;
3. examine international collaboration networks;
4. identify dominant topic clusters and keywords; and
5. reveal research gaps that may inform future research agendas.

The findings of this study are expected to provide both theoretical and practical contributions by offering a comprehensive scientific mapping for researchers, practitioners, and policymakers in advancing research and the implementation of AR in primary education. Furthermore, this study is anticipated to serve as a foundation for designing more rigorous experimental studies and strengthening international research collaborations.

2. Theoretical Framework

2.1. Augmented Reality in Constructivist Learning Theory

The implementation of AR in learning is grounded in constructivist theory, which posits that learners actively construct knowledge through interaction with their environment (Piaget, 1970; Vygotsky & Cole, 1978). In this context, AR provides opportunities for students to enrich the process of meaning-making in a contextual manner by integrating virtual objects with real-life situations. AR embodies the principle of *learning by doing*, where learners are not merely passive recipients of information but actively engage with dynamic and manipulable visualizations.

Since elementary school pupils are in the tangible operational stage, where direct and visually supported learning experiences are crucial, the usage of AR in primary education is very pertinent. By offering interactive three-dimensional representations that promote conceptual understanding and meaningful learning experiences, augmented reality (AR) has been shown in recent research to lessen cognitive overload related to abstract concepts (Buchner et al., 2022; H. Y. Chang et al., 2022). Additionally, it has been discovered that AR-based learning environments complement contextual and experiential learning approaches in primary education by improving student engagement, information retention, and active involvement (Singh et al., 2024; Tlili et al., 2022). Thus, in elementary education, AR can be conceptualized as a link between direct experiential learning and abstract thinking.

2.2. Pedagogical Affordances and Challenges of Augmented Reality

The idea of affordances, which refers to a technology's capacity to assist particular learning tasks, is the foundation of educational technology. Because of its unique pedagogical affordances such as the ability to visualize complex objects, high levels of interactivity, and immersive learning experiences AR is especially well-suited for fields like science, mathematics, and others that call for strong spatial representations (Dwivedi et al., 2022; Tlili et al., 2022)

However, user preparedness and instructional design also play a role in AR's efficacy. The use of augmented reality in educational settings is still hampered by a number of issues, according to recent empirical research (Buchner et al., 2022; Gonnermann-Müller & Krüger, 2025; Zekeik et al., 2025). These issues include limited technological infrastructure, insufficient teacher digital competencies, challenges integrating AR into current curricula, and worries about managing cognitive load. As a result, learner characteristics, learning situation, and pedagogical design all significantly affect the educational impact of augmented reality. This viewpoint contributes to the explanation of the disparity in earlier research on the use of AR in education.

2.3. Bibliometric Analysis as a Scientific Mapping Approach

Bibliometric analysis represents an appropriate approach for examining the development of AR research within the field of education. Through bibliometric methods, it is possible to evaluate and visualize patterns of scientific publication, including research trends, collaboration networks, and the structure of research topics (Donthu et al., 2021). This approach enables the identification of key actors, relationships among researchers, and the evolution of concepts within a particular domain of study.

In this study, bibliometric analysis functions as an analytical framework for investigating the development of AR research over time. In contrast to meta-analysis, which primarily focuses on effect sizes, bibliometric analysis provides a broader overview of the scientific landscape, including the distribution of countries, institutional influence, and thematic research clusters. With the support of VOSviewer, relationships among keywords, citations, and collaborations can be visualized in the form of networks, thereby facilitating the interpretation of research patterns (Donthu et al., 2021; Tomaszewski, 2023; van Eck & Waltman, 2010).

2.4. Integrative Framework: Linking Learning Theory, Technology, and Research Trends

The theoretical stances discussed in the preceding sections serve as a basis for creating an integrated framework that links bibliometric analysis, augmented reality (AR), and learning theory. While affordance theory explains how technology features allow learners to perceive and carry out behaviors that facilitate learning, constructivist theory proposes that learners actively construct knowledge through meaningful engagement with their environment. AR provides chances to integrate digital and physical components in educational settings, resulting in contextualized and experienced learning environments that may improve students' conceptual understanding and engagement (Tlili et al., 2022; Dwivedi et al., 2023).

However, technological capabilities are not the only factors that determine AR's instructional usefulness. Pedagogical design, teacher competencies, technology accessibility, and the fit between learning goals and digital resources all influence how effective it is. According to recent studies, in order to optimize the educational affordances of immersive technologies and reduce implementation barriers, proper instructional planning and sufficient teacher preparation are necessary (Buchner et al., 2022; Gonnermann-Müller & Krüger, 2025).

A methodical way to look at the intellectual framework and development of scientific fields is through bibliometric study. Within a field of study, it makes it easier to identify new themes, collaborative networks, publishing patterns, and significant contributors (Donthu et al., 2021). Additionally, bibliometric techniques are being used more and more to comprehend how educational technologies and immersive learning environments are developing (Tlili et al., 2022). The current study provides a thorough framework for comprehending how learning theories, technical advancements, and research trends all work together to influence the development of augmented reality in primary education by combining various viewpoints.

3. Method

3.1. Research Design

This study employs a bibliometric mapping design using a quantitative approach. This approach aims to analyze trends, patterns, and relationships among scientific publications related to the research topic. The bibliometric analysis is conducted using data retrieved from internationally reputable databases, such as Scopus, and is supported by analytical tools including VOSviewer and Biblioshiny. Through this method, the study is able to objectively and systematically identify research developments, dominant keywords, and potential directions for future research.

3.2. Data Source and Search Strategy

The search strategy began with selecting the appropriate database. The researchers chose the Scopus database for several reasons: (1) its extensive and multidisciplinary coverage; (2) Scopus indexes credible and high-quality sources that have undergone rigorous evaluation by the Content Selection & Advisory Board (CSAB); (3) its metadata are comprehensive covering titles, abstracts, keywords, affiliations, citations, DOIs, and references which are essential for co-citation, co-authorship, and keyword-mapping analyses; (4) Scopus aggregates publications from thousands of publishers worldwide, allowing global-scale analyses of research development, international collaboration, and scholarly influence; and (5) Scopus data can be efficiently exported to various bibliometric analysis tools, including VOSviewer and Biblioshiny, thereby facilitating faster and more efficient scientific mapping.

After selecting Scopus as the primary database, the next step was determining the search keywords. Keyword formulation was aligned with the research objectives (Ansorge, 2024). The focus of this study is the utilization of Augmented Reality in primary-school contexts. Accordingly, the keyword "Augmented Reality" was used to locate articles related to the technology, while the terms "Primary School" and "Elementary School" were applied to identify studies conducted in the primary-education setting. Boolean operators AND and OR were employed to refine the search and retrieve specific and relevant publications. The search was carried out using the title–abstract–keyword fields, as follows:

Title-abstrak-keyword: (("augmented reality") AND ("primary school" OR "elementary school"))

After obtaining the relevant data, the researcher established inclusion and exclusion criteria to guide article selection and ensure the quality and relevance of the study. As presented in Table 1, these criteria cover the publication period, document type, language, research focus, and research design.

Table 1. Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Time range	2005-2024	Documents published before 2005 or after 2024
Document type	Peer-reviewed journal articles	Non–peer-reviewed documents such as books, book chapters, conference proceedings, editorials, and others
Language	English-language documents	Non-English documents
Research focus	Augmented Reality in primary education	Augmented Reality outside primary education
Research design	Quantitative, qualitative, and mixed-methods studies	Review articles, conceptual papers, and theoretical papers

Following the application of the inclusion and exclusion criteria, the selected articles are subjected to bibliometric analysis. This study maps research trends, productivity, and thematic developments in the field of Augmented Reality in primary education. The data and visualizations are presented in the form of graphs, tables, and network maps, generated through bibliometric analysis software. Table 1 presents several key parameters.

3.3. Data Collection

The data collection process in this study follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. This approach was adopted to ensure complicance with international scientific standards, enhance transparency in document selection, minimize potential bias, and improve the reproducibility of the review process (Donthu et al., 2021; Page et al., 2021). PRISMA consists of four stages: identification, screening, eligibility, and inclusion. This process is summarized in Figure 1.

The initial search yielded 667 documents from the Scopus database. During the screening stage, 72 documents were excluded for not meeting the specified time range, followed by the removal of 359 non–peer-reviewed documents and 5 non-English articles, resulting in 231 eligible articles. In the eligibility stage, the researcher conducted a manual review based on titles and abstracts. The results indicated that 25 articles did not meet the criteria, comprising 17 articles that did not align with the research focus and 8 articles categorized as literature reviews. Consequently, a total of 206 articles were deemed suitable for further analysis.

3.4. Data Analysis

The retrieved data were stored in comma-separated values (CSV) format to facilitate bibliometric analysis using VOSviewer and Biblioshiny (Saputra et al., 2022). The primary objective is to evaluate research development through two main approaches, namely performance analysis and science mapping (Erlande et al., 2025). Performance analysis focuses on research productivity and impact, including the number of publications, annual trends, the most productive authors and countries, and the most influential articles. Bibliometrix systematically computes these indicators, enabling researchers to identify key contributors and understand the growth dynamics of a particular research field (Donthu et al., 2021).

Meanwhile, science mapping aims to depict the intellectual structure and relationships among concepts through co-authorship, co-citation, and keyword co-occurrence analyses. VOSviewer is utilized to generate network maps that illustrate thematic clusters, research trends, and the evolution of research topics, thereby facilitating a deeper understanding of knowledge structures and emerging scientific directions. The integration of VOSviewer and Bibliometrix enables a comprehensive analysis, ranging from the evaluation of publication performance to the mapping of knowledge structures within the scientific literature.

Table 2 summarizes the bibliometric parameters used to assess research productivity, scholarly impact, and thematic content in the selected literature.

Table 2. Bibliometric parameters.

Category	Parameter	Description
Productivity	Number of publications per year	Measures the growth trend of research over time.
	Number of articles per author / institution / country	Identifies the most productive actors in the field of Augmented Reality.
impact	Number of citations per article	Measures the influence or relevance of an article within the scientific community. For instance, articles ranked at the top indicate those receiving the highest number of citations compared to others within the same journal (Azer SA, 2017)
	Most productive journals	dentifies journals that publish the highest number of articles on the topic.
Conten	Keyword co-occurrence	Identifies frequently co-occurring terms to reveal dominant research themes.
	Clustering	Explores thematic trends within the content of the articles.

Trending topics	Maps major topics and their evolution over time

Overall, Table 2 organizes the analysis into three complementary dimensions. Productivity indicators trace publication growth and identify the most active authors, institutions, and countries; impact indicators assess scholarly influence through citations and leading journals; and content indicators reveal dominant themes and their evolution through keyword co-occurrence, clustering, and trending-topic analysis.

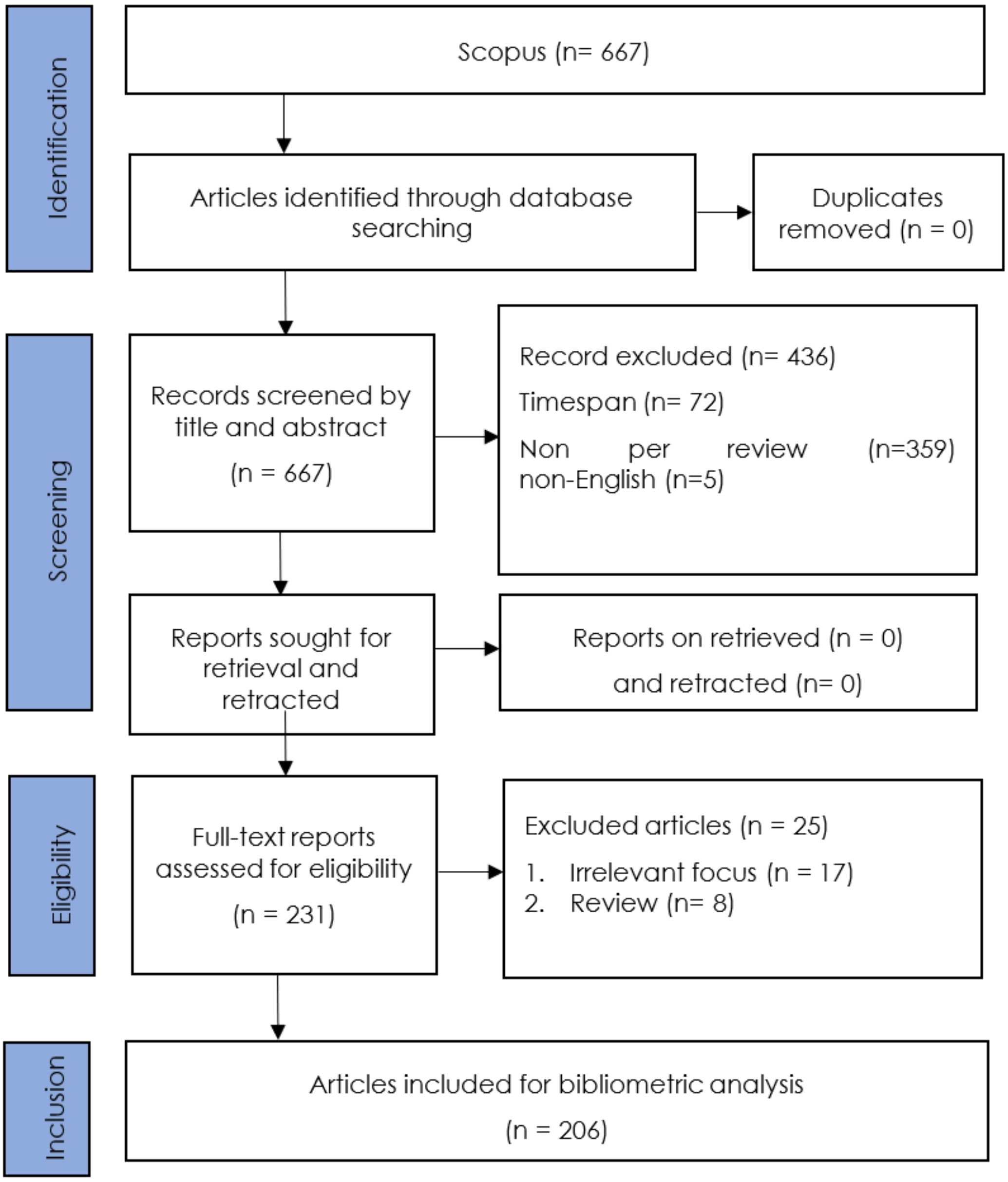

Figure 1. PRISMA flow diagram

3.5. Validity and Reliability

This study's validity and reliability are guaranteed by a methodical and open research strategy. Because of its broad coverage of excellent peer-reviewed publications and its widespread acceptance in bibliometric studies, the Scopus database is used as the major data source to establish data validity (Donthu et al., 2021). This study uses carefully chosen keywords in conjunction with Boolean operators within the TITLE-ABS-KEY search field to guarantee construct validity and reduce the possibility of irrelevant or missing records. To improve data correctness, comprehensiveness, and repeatability, the search strategy and document selection processes were created in accordance with accepted bibliometric criteria (Donthu et al., 2021; Tomaszewski, 2023).

By using the PRISMA 2020 standards, which offer a uniform framework for the identification, screening, eligibility, and inclusion processes, procedural dependability is preserved and the review process is transparent and repeatable (Page et al., 2021). Additionally, using VOSviewer with constant parameter settings such as minimum threshold values and normalization techniques across all stages of analysis ensures analytical dependability. By allowing for the cross-validation of patterns found in the scientific literature, the integration of several bibliometric techniques, such as co-authorship, co-citation, and keyword co-occurrence analyses, further enhances the study's findings' robustness, consistency, and credibility (Donthu et al., 2021; Tomaszewski, 2023).

4. Findings

4.1. Publication Structure

Publications on Augmented Reality (AR) in primary education have shown a continuous increase, as illustrated in Figure 2. This growth can be categorized into three distinct phases.

In the first phase (2006–2012), publication growth remained limited, with only 4 publications (2.47%) recorded during this period. The highest number of publications occurred in 2009, with 2 publications, and there were even years within this phase in which no studies on AR in primary education were published. Therefore, this period can be characterized as the *embryonic phase*.

The second phase (2013–2018) can be identified as the *growth phase*, as the number of publications increased compared to the embryonic phase. A particularly significant rise occurred in 2018, with 12 publications. Although the growth during this phase was somewhat fluctuating, the overall trend indicates a clear increase, with a total of 38 publications (18.4%) recorded during this period.

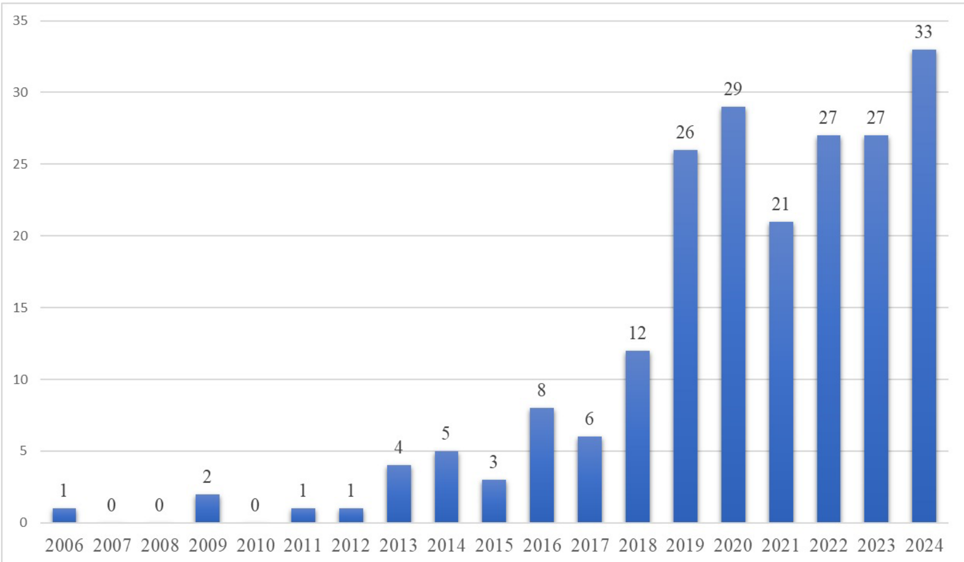

Figure 2. Publication growth

The third phase (2019–2024) is characterized by a substantial surge in the overall number of publications compared to the previous phases, with a total of 163 publications (79.12%). The peak of publication output occurred in 2024, with 33 publications. This period can therefore be described as the *golden phase*. The upward trend is expected to continue in the coming years.

Publication productivity has also been analyzed based on geographical distribution. Table 3 presents the top 20 out of 60 regions with the highest number of publications. Taiwan ranks first with 50 publications and 3,191 citations. Malaysia occupies the second position with 28 publications and 460 citations, followed by Indonesia in third place with 25 publications and 481 citations.

Table 3. State productivity

Continent	Region	Rank	Documents	Citations
Asia	Taiwan	1	50	3191
	Malaysia	2	28	460
	Indonesia	3	25	481
	China	4	12	219
	South Korea	5	12	360
	Saudi Arabia	6	9	319
	Singapore	11	7	264
	Iraq	15	4	39
	Thailand	20	3	14
Europe	United Kingdom	7	9	759
	Greece	8	8	175
	Spain	9	8	673
	Turkey	10	8	273
	Cyprus	12	6	354
	Luxembourg	13	5	72
	Austria	14	4	38
	Egypt	17	3	65
	Italy	18	3	105
	Portugal	19	3	13
Oceania	Australia	16	3	21

Interestingly, both Malaysia and Indonesia demonstrate higher publication outputs than 19 other countries; however, their citation counts remain lower than those of the United Kingdom, which ranks seventh with 759 citations from 9 publications, and Spain, which ranks ninth with 673 citations from 8 publications.

Table 3 also indicates the absence of publications on Augmented Reality in primary education from countries located in regions of the African and American continents.

4.2 Most Influential Journals, Authors, and Documents

The primary sources of publications on Augmented Reality in primary education are presented in Table 4. Among the top 20 sources publishing research in this field, Computers & Education ranks first with 1,101 citations from 6 publications. This is followed by Educational Technology & Society with 787 citations from 7 publications, and Interactive Learning Environments with 657 citations from 10 publications. In fourth place is Virtual Reality, which has accumulated 434 citations from a single publication.

A closer examination of these top four sources suggests that a higher number of publications does not necessarily correspond to a higher citation count. In fact, some journals with relatively few publications demonstrate substantial citation impact. For example, Virtual Reality has only one publication yet has garnered 434 citations, indicating a strong scholarly influence despite its limited output.

Table 4. Reputable Sources

No	Source	H_index	TC	NP
1	Computers and Education	6	1101	6
2	Educational Technology and Society	7	787	7

No	Source	H_index	TC	NP
3	Interactive Learning Environments	8	657	10
4	Virtual Reality	1	434	1
5	Educational Technology Research and Development	4	321	4
6	Education and Information Technologies	8	296	12
7	Journal of Computer Assisted Learning	4	295	4
8	British Journal af Educational Technology	3	230	3
9	Environmental Education Research	1	212	1
10	Studies in Educational Evaluation	1	207	1
11	International Journal af Instruction	3	205	3
12	Universal Access In The Information Society	3	173	3
13	International Journal af Interactive Mobile Technologies	6	144	10
14	Ieee Access	2	112	2
15	Turkish Online Journal of Educational Technology	1	106	2
16	Displays	1	98	1
17	Education Sciences	3	92	3
18	Applied Sciences (Switzerland)	3	86	3
19	Sustainability (Switzerland)	5	79	5
20	Egitim Ve Bilim	1	78	1

The most influential authors in Augmented Reality research are presented in Table 5. Based on the data, a total of 10 authors were identified, each with varying numbers of publications. The most prolific author is Gwo-Jen Hwang from National Taiwan University of Science and Technology, with 7 publications and a total of 1,339 citations. This is followed by Chun-Hung Chen from National Taichung University of Education, who has published 6 articles with a total of 403 citations.

Table 5. Most Influential Authors

No	Author	Afiliation	NP	TC	TCpY
1	Hwang G-J	National Taiwan University of Science and Technology, Taiwan	7	1339	20,79
2	Chen C-H	National Taichung University of Education, Taiwan	6	403	9,60
3	Liu Y-C	Chang-Gung University, Taiwan	4	281	7,96
4	Lu S-J	National Taipei University of Education, Taiwan	4	281	7,96
5	Wen Y	Nanyang Technological University, Singapore,	5	229	9,71
6	Lee J	Yonsei University, Seoul, South Korea	4	120	5,45
7	Chou Y-Y	National Taichung University of Science and Technology, Taichung, Taiwan	3	100	4,51
8	Eh Phon DNE	Universiti Malaysia Pahang, Malaysia	3	48	2,29
9	Lavicza Z	Johannes Keppler University Linz, Austria	4	38	2,11
10	Haas B	Johannes Keppler University Linz, Austria	3	37	2,64

Table 5 indicates that several authors are affiliated with the same institution, notably Zsolt Lavicza and Bettina Haas from Johannes Kepler University Linz. Furthermore, when examined by country of origin, the majority of authors are based in Asia, with Taiwan being the most dominant, contributing five authors. This is followed by Austria with two authors, and Singapore, South Korea, and Malaysia, each represented by one author.

The most significant publications within the literature on Augmented Reality in primary education are subsequently identified through document citation analysis, as presented in Table 6.

Table 6. The Twenty Most Influential Articles

No	Author	Region	Sources	Title	TC	TCpY
1	(Chiang et al., 2014a)	Taiwan	Educational Technology & Society	An Augmented Reality-Based Mobile Learning System to Improve Students' Learning Achievements and Motivations in Natural Science Inquiry Activities	463	38,58
2	(Kerawalla et al., 2006)	United Kingdom	Virtual Reality	"Making it real": exploring the potential of augmentesd reality for teaching primary school science	434	21,70
3	(S.-C. Chang & Hwang, 2018)	Taiwan	Computer & Education	Impacts of an augmented reality-based flipped learning guiding approach on students' scientific project performance and perceptions	301	37,63
4	(Chen & Tsai, 2012)	Taiwan	Computer & Education	Interactive augmented reality system for enhancing library instruction in elementary schools	265	18,93
5	(Hwang et al., 2016)	Taiwan	Interactive Learning Environments	Effects of an augmented reality-based educational game on students' learning achievements and attitudes in real-world observations	218	21,80
6	(Chiang et al., 2014b)	Taiwan	Computer & Education	Students' online interactive patterns in augmented reality-based inquiry activities	218	18,17
7	(Lu & Liu, 2015)	Taiwan	Environmental Education Research	Integrating augmented reality technology to enhance children's learning in marine education	212	19,27
8	(Alalwan et al., 2020)	Saudi Arabia	Studies in Educational Evaluation	Challenges and Prospects of Virtual Reality and Augmented Reality Utilization among Primary School Teachers: A Developing Country Perspective	207	34,50

No	Author	Region	Sources	Title	TC	TCpY
9	(Furió et al., 2015)	Spain	Computer Assisted Learning	Mobile learning vs. traditional classroom lessons: a comparative study	183	16,64
10	(López-Faican & Jaen, 2020)	Ecuador	Computer & Education	EmoFindAR: Evaluation of a mobile multiplayer augmented reality game for primary school children	161	26,83
11	(Liu et al., 2009)	Taiwan	Educational Technology & Society	Outdoor Natural Science Learning with an RFID-Supported Immersive Ubiquitous Learning Environment	160	9,41
12	(Demitriadou et al., 2020)	Cyprus	Education and Information Technologies	Comparative evaluation of virtual and augmented reality for teaching mathematics in primary education	153	25,50
13	(Lai et al., 2019)	Taiwan	British Journal of Educational Technology	An augmented reality-based learning approach to enhancing students' science reading performances from the perspective of the cognitive load theory	153	21,86
14	(Wen, 2021)	Singapore	Educational Technology Research and Development	Augmented reality enhanced cognitive engagement: designing classroom-based collaborative learning activities for young language learners	117	23,40
15	(Joo-Nagata et al., 2017)	Chile	Computer & Education	Augmented reality and pedestrian navigation through its implementation in m-learning and e-learning: Evaluation of an educational program in Chile	113	12,56
16	(Pérez-López & Contero, 2013)	Spain	TOJET: The Turkish Online Journal of Educaçnal Technology	Delivering Educational Multimedia Contents Through an Augmented Reality Application: A Case Study on its Impact on Knowledge Acquisition and Retention	106	8,15

No	Author	Region	Sources	Title	TC	TCpY
17	(Lin et al., 2016)	Taiwan	Display	Augmented reality in educational activities for children with disabilities	98	9,80
18	(Rossano et al., 2020)	Italy	IEEE Access 8	Augmented reality to support geometry learning	93	15,50
19	(R.-C. Chang et al., 2016)	Taiwan	Interactive Learning Environments	Developing an interactive augmented reality system as a complement to plant education and comparing its effectiveness with video learning	89	8,90
20	(Wu et al., 2018))	Taiwan	Interactive Learning Environments	Impacts of integrating the repertory grid into an augmented reality-based learning design on students' learning achievements, cognitive load and degree of satisfaction	88	11,00

Consistent with the findings in Table 3, Table 5 shows that Taiwan contributes the highest number of influential articles, with a total of 11 publications in the field of Augmented Reality.

The study by Ting-Hsin Chiang et al. (2014) received the highest number of citations, totaling 463, with the article entitled *"An Augmented Reality-Based Mobile Learning System to Improve Students' Learning Achievements and Motivations in Natural Science Inquiry Activities."* This exceeds the citation count of Lucinda Kerawalla et al. (2006), whose article *"Making it real: Exploring the potential of augmented reality for teaching primary school science"* has 434 citations. Notably, Ting-Hsin Chiang is the only author with two highly influential documents, the second being *"Students' online interactive patterns in augmented reality-based inquiry activities,"* which has received 218 citations and ranks sixth.

Overall, these findings indicate that the body of literature on Augmented Reality in primary education remains relatively limited. Even among the top 20 most cited articles, the lowest citation count is 88, suggesting a moderate level of scholarly concentration within the field.

4.3 Most Frequently Discussed Themes

Keywords serve as a form of generalization or representation of dominant research themes (Erlande et al., 2025). Through mapping and clustering processes, terms extracted from keywords allow for a clearer identification of research topics. From the 206 documents analyzed, a total of 555 keywords were identified. By applying a minimum occurrence threshold of three, 44 keywords met the criteria for analysis. Figure 3 presents a keyword mapping based on frequency of occurrence, revealing three conceptual clusters distinguished by different colors.

4.3.1. Cluster 1. Integrating Augmented Reality in Mathematics and Science Learning in Primary Education (Red)

The red cluster is centered around the term *"augmented reality"* (138 occurrences), which is connected to 146 nodes and represents the most frequent term within this cluster. Overall, this term is strongly associated with the core concepts of the other clusters.

Thematically, the red cluster focuses on the integration of Augmented Reality in mathematics and science learning at the primary school level. Other frequently occurring terms include "*primary school*" (9 occurrences) and "*usability*" (7 occurrences).

The main terms identified within this cluster include: ar; augmented reality; collaborative learning; e-learning; education; elementary school; elementary school students; geometry; learning; learning disabilities; learning media; mathematics; mathematics education; mobile application; motivation; primary school; reading comprehension; science; science learning; situated learning; storytelling; and usability.

4.3.2. Cluster 2. Challenges and Opportunities in the Implementation of Emerging Technologies for Teachers (Green)

The dominant theme in the green cluster concerns the challenges and opportunities associated with the implementation of emerging technologies for teachers. The most frequently occurring term in this cluster is "*augmented reality (AR)*" (14 occurrences), which is connected to 171 nodes. Other prominent terms include "*primary education*" (8 occurrences) and "*game-based learning*" (7 occurrences).

The main terms associated with this cluster include: augmented reality (ar); cognitive load; digital game-based; learning educational; technology; flow experience; game-based learning; marine education; observation; primary education; primary school students; teacher training; and learning motivation.

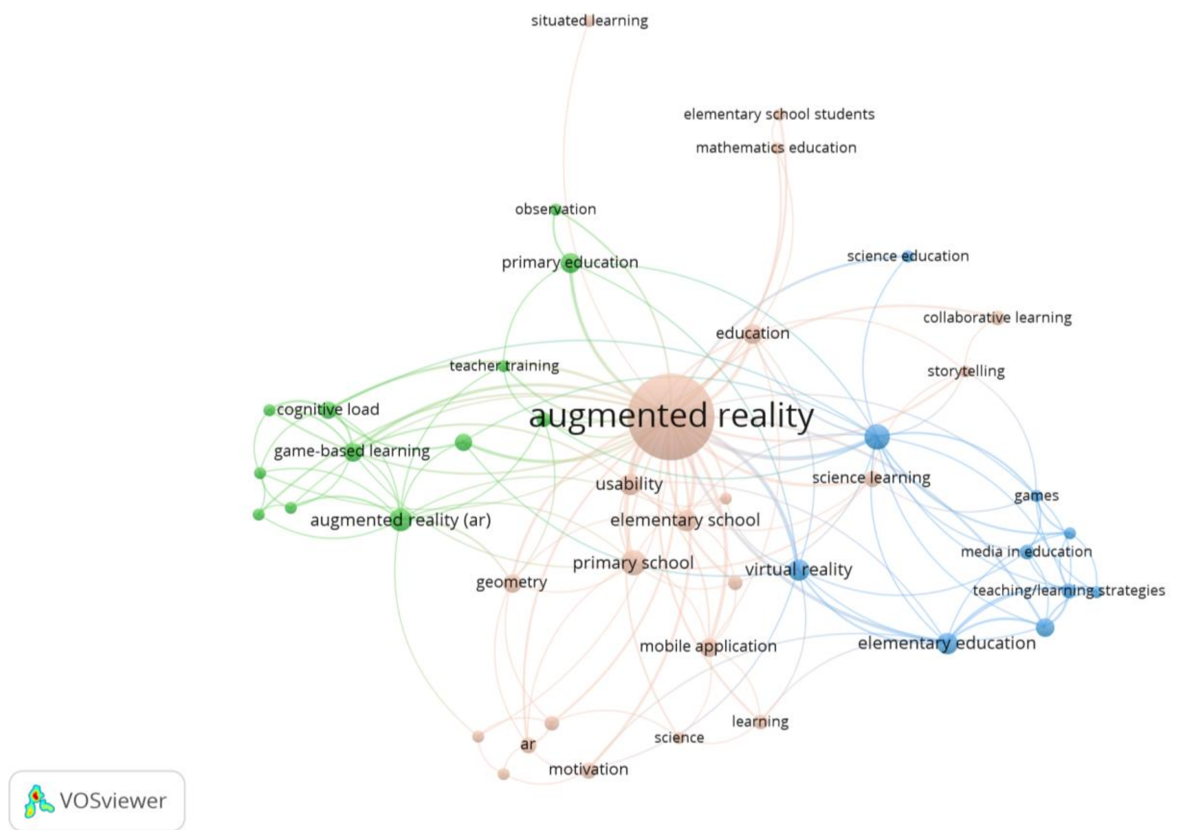

Figure 3. Research themes augmented reality in primary school.

4.3.3. Cluster 3. Interactive and Collaborative Learning Environments Based on Augmented Reality and Virtual Reality in Primary Education (Blue)

The blue cluster relates to interactive and collaborative learning environments based on Augmented Reality and Virtual Reality in primary education. The most frequently occurring term in this cluster is "*mobile learning*" (12 occurrences), which is connected to 28 nodes, making it the most prominent term within this cluster. This is followed by the terms "*elementary education*" and "*virtual reality.*"

Other important terms within the blue cluster include: *interactive learning environments; augmented and virtual reality; cooperative/collaborative learning; elementary education; games; media in education; mobile learning; science education; teaching/learning strategies;* and *virtual reality.*

4.4. Trending Topics

Keyword analysis facilitates the identification of popular research topics across both past and current periods (Pesta et al., 2018). The color of keyword nodes indicates the temporal trends of research topics (Kuzior & Sira, 2022). In addition, node size is used to represent the level of popularity of a given topic. In general, the more yellow the node color and the larger its size, the more prominent and emerging the topic is. The topic network is illustrated in Figure 4.

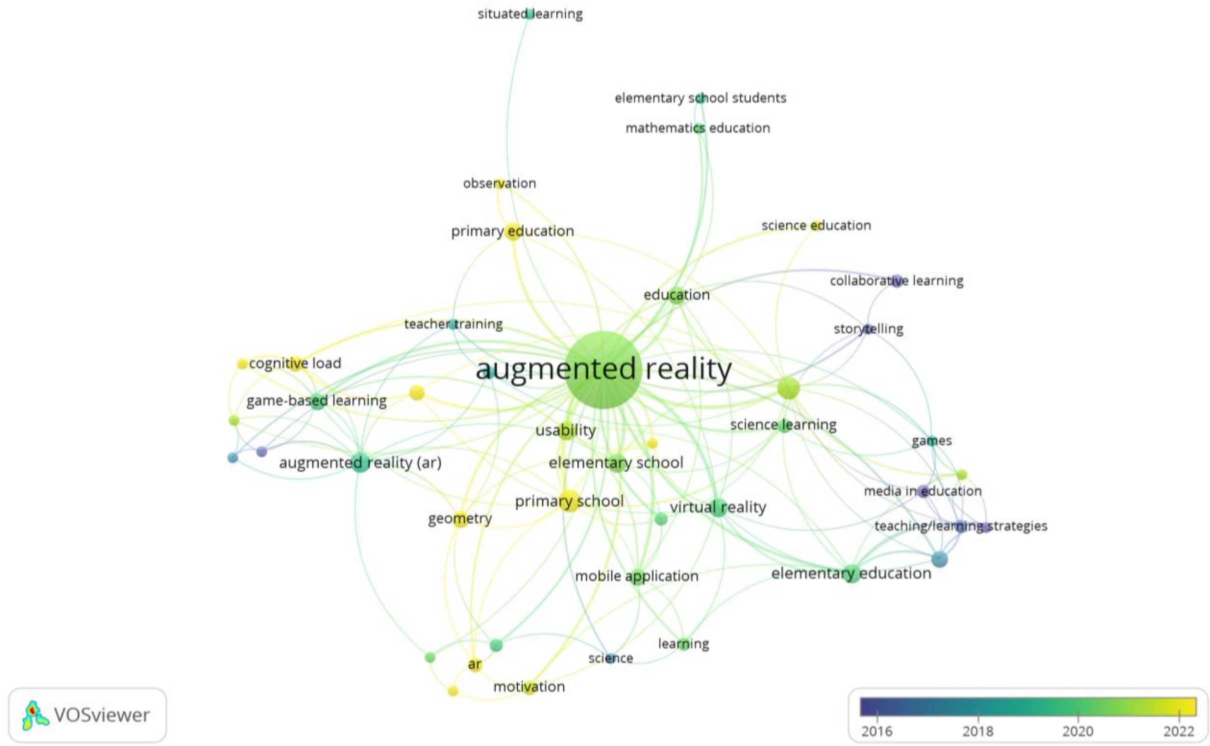

Figure 4. Trending Topics in Augmented Reality Studies in Elementary Education

In terms of research trends, Figure 4 indicates that "*primary education,*" "*geometry,*" "*cognitive load,*" and "*learning motivation*" were among the most prominent topics in 2022. Meanwhile, topics that were particularly popular during the 2020–2022 period include "*augmented reality,*" "*mobile learning,*" and "*education.*"

In addition, the period between 2018 and 2020 was characterized by trends in "*science learning,*" "*games,*" "*teacher learning,*" and "*educational technology*." Topics that emerged prior to 2018 can be considered relatively outdated, as they are no longer at the forefront of current research developments.

5. Discussion

5.1. Constructivist Perspective on the Development of AR Research in Elementary Education

The growing acknowledgment of augmented reality (AR) as more than just a technology advancement is reflected in the growing number of publications on AR in elementary education. From a constructivist standpoint, this pattern shows a growing interest in educational settings that let students actively create knowledge by interacting with contextualized experiences (Piaget, 1970; Vygotsky & Cole, 1978). Because primary school pupils are in the concrete operational stage, augmented reality (AR) gives kids the chance to connect abstract ideas with real-world experiences by visualizing and interacting with virtual items. Thus, a paradigm change toward immersive and student-centered learning settings in primary education may be indicated by the explosive expansion of AR research, especially after 2019.

5.2. What Makes Taiwan the Leader in AR Research for Elementary Schools?

Taiwan's supremacy in AR research can be explained by long-term educational policy, consistent investment in digital learning initiatives, and academic productivity. Through governmental initiatives like the e-Learning Promotion Program and the Digital Learning Enhancement Plan, which foster cooperation between academic institutions, educational institutions, and the technology sector, Taiwan has actively pushed technology-enhanced learning. These programs give researchers access to financing options, real classroom environments for testing, and technical infrastructure. Taiwan's robust research ecosystem and citation impact are further enhanced by the presence of globally renowned experts like Hwang G.-J and Chen C.-H. This result implies that institutional support, national innovation strategies, and pedagogical factors all have an impact on the advancement of AR research.

5.3. Dominant Research Themes Are Explained by Pedagogical Affordances

Affordance theory provides an explanation for why science and math education predominate in AR research. According to Dwivedi et al. (2022) and Tlili et al. (2022), AR's distinctive pedagogical affordances, including as three-dimensional visualization, real-time interaction, and immersive experiences, make it especially appropriate for fields that demand spatial reasoning and conceptual visualization. Researchers are placing more emphasis on game-based learning, teacher preparedness, and cognitive load, according to the keyword clusters found in this study. These themes align with previously noted obstacles to AR deployment, suggesting that academics have turned their focus from just analyzing learning outcomes to comprehending the circumstances in which AR can be successfully incorporated into teaching methods.

5.4. New Research Trends Show a Developing Field

AR research in elementary education appears to be approaching a more developed stage, as evidenced by the shift in research themes from basic science teaching to cognitive engagement, emotional learning, and mobile learning. While more recent research aims to investigate how AR can promote higher-order thinking abilities, emotional development, and collaborative learning experiences, earlier studies mostly concentrated on evaluating whether AR enhances learning outcomes. These advancements support constructivist presumptions that meaningful learning happens when students actively engage in the creation of knowledge in real-world, socially mediated environments.

5.5. Research and Educational Practice Implications

Even though augmented reality has a lot of promise to improve educational experiences, its effective application depends on the caliber of instructional design, teacher proficiency, and technical accessibility. The results suggest that future research on AR integration in elementary classrooms should go beyond efficacy-oriented studies and investigate sustainable pedagogical methods. To optimize the educational affordances of augmented reality, authorities should also think about funding teacher professional development and digital infrastructure. As a result, bibliometric evidence offers insights into how new technologies might facilitate more relevant, contextualized, and collaborative learning environments in elementary education in addition to revealing the philosophical framework of AR research.

6. Conclusion

This study concludes that augmented reality has evolved into a prominent and increasingly influential topic in primary education, as evidenced by a substantial rise in both publications and citations over the past two decades. Augmented reality has been shown not only to enhance students' understanding of abstract concepts, but also to improve their motivation, engagement, and overall learning experiences. The dominance of Taiwan and several other Asian countries highlights the region's role as a leading hub for innovation and development in the application of augmented reality in primary education. Furthermore, the mapping of key themes and research trends reveals a shift in focus from mere application development toward pedagogical effectiveness, immersive learning experiences, and teacher readiness. Overall, these findings underscore that augmented reality represents a strategic technology for improving the quality of primary education by fostering more interactive, collaborative, and constructivist learning environments.

Limitation

Although the bibliometric analysis conducted in this study provides meaningful insights, it is important to acknowledge two major methodological limitations related to database selection and language coverage. Due to Scopus's reliance on English-language publications, significant studies published in other languages—particularly non-English works that make substantial contributions to this field—may have been overlooked. This language barrier may introduce bias, as regional perspectives and research traditions documented in other languages can be underrepresented. Furthermore, the coverage of Scopus remains relatively limited when compared to more inclusive databases, despite its extensive indexing of high-quality, reputable English-language publications.

Recommendation

To increase the thoroughness of the literature coverage, this study can be improved by adding databases like Web of Science, ScienceDirect, Google Scholar, ERIC, and Dimensions. In order to obtain a larger and more representative body of literature, future research may also take into account merging complementary datasets and using multilingual search techniques. There may be differences in how important concepts are interpreted because bibliometric analysis mostly uses information taken from titles, abstracts, and keywords rather than full-text articles.

In order to gain a deeper understanding of pedagogical designs, implementation challenges, and learning outcomes related to augmented reality, it is recommended that future research on augmented reality in elementary education combine bibliometric approaches with qualitative methods, such as content analysis or systematic literature reviews. In order to further understand the contextual elements influencing the successful integration of augmented reality in primary education, future study should also include comparison assessments across educational levels, subject areas, and geographical regions.

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Conflict of Interest Statement

The authors declares that there is no conflict of interest.

Declaration of Generative AI and AI-assisted Technologies

This manuscript was prepared with the assistance of generative artificial intelligence tools, including ChatGPT, Claude, and QuillBot. These tools were used solely to support initial drafting, language editing, and manuscript organization. All conceptualization, critical analysis, interpretation of findings, and final revisions were undertaken by the authors. The authors assume full responsibility for the accuracy, originality, and integrity of the content presented in this work.

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