

**RESEARCH TRENDS ON THE DEVELOPMENT OG AUGMENTED REALITY
(AR)-BASED INTERACTIVE LEARNING MATERIALS TO IMPROVE LEARNING
OUTCOMES FOR ELEMENTARY SCHOOL: A BIBLIOMETRIK ANALYSIS
(2022-2026)**

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ABSTRACT

The rapid development of digital technology has had an impact on the learning system in primary schools and increased pupils' screen time. Currently, teachers in Indonesia still lack adequate digital competence, which is one of the factors affecting pupils' learning outcomes. This study aims to analyse research trends regarding the development of Augmented Reality (AR)-based interactive learning media to improve the learning outcomes of primary school students using a bibliometric approach. Data were obtained from 37 documents indexed in the Scopus database from 2022-2026. Data analysis was conducted using the Scopus Analyze feature and VOSviewer software. The results indicate a significant increase in the number of publications, particularly between 2023 and 2025. Indonesia is the country contributing the most publications. Social Sciences is the dominant field of study. Keyword co-occurrence analysis identified three main clusters related to the implementation of AR in learning, the effectiveness of AR technology use, and the impact of AR on learning outcomes. Furthermore, overlay visualisations indicate a shift in research trends towards the use of technology in learning and the application of Augmented Reality in primary schools. Overall, these findings suggest that research on Augmented Reality in primary education continues to evolve and still offers ample opportunities for future studies within different educational contexts.

Keywords: Augmented Reality, Bibliometric Analysis, Elementary School, Scopus, VOSviewer

ABSTRAK

Perkembangan pesat teknologi digital berdampak pada sistem pembelajaran di sekolah dasar dan meningkatkan waktu layar siswa. Saat ini, guru di Indonesia masih kurang memiliki kompetensi digital yang memadai, yang menjadi salah satu faktor yang memengaruhi hasil belajar siswa. Penelitian ini bertujuan untuk menganalisis tren penelitian mengenai pengembangan media pembelajaran interaktif berbasis Augmented Reality (AR) untuk meningkatkan hasil belajar siswa sekolah dasar dengan pendekatan bibliometrik. Data diperoleh dari 37 dokumen

yang terindeks dalam basis data Scopus dari tahun 2022-2026. Analisis data dilakukan menggunakan fitur Scopus Analyze dan perangkat lunak VOSviewer. Hasil penelitian menunjukkan peningkatan signifikan dalam jumlah publikasi, terutama antara tahun 2023 dan 2025. Indonesia menjadi negara paling banyak menyumbang publikasi. Ilmu Sosial merupakan bidang studi yang dominan. Analisis ko-kemunculan kata kunci mengidentifikasi tiga kluster utama yang berkaitan dengan implementasi AR dalam pembelajaran, Efektivitas penggunaan teknologi AR, dan dampak AR terhadap hasil belajar. Selain itu, visualisasi overlay menunjukkan pergeseran tren penelitian menuju penggunaan teknologi dalam pembelajaran dan pemanfaatan Augmented Reality di sekolah dasar. Secara keseluruhan, temuan ini menunjukkan bahwa penelitian tentang Augmented Reality dalam pendidikan dasar terus berkembang dan masih banyak menawarkan peluang untuk studi dimasa depan dalam konteks pendidikan yang berbeda.

Kata Kunci: Augmented Reality, Analisis Bibliometrik, Sekolah Dasar, Scopus, VOSviewer

A. Introduction

Over the past decade, technology has become a key factor in the transformation of education by driving more varied and interactive learning innovations (Sidiq et al., 2025; Malay et al., 2024). The use of technology also supports the development of digital competences and improves the quality of learning for teachers and pupils (Hariyasasti, 2025; Baroroh et al., 2024). In primary education, the application of technology plays a vital role as this stage forms the foundation for pupils' academic development in subsequent stages of education (Ananda et al., 2025). Therefore, an in-depth examination of the application of technology in primary education is required.

One innovation in the integration of learning technology is the use of interactive media based on Augmented Reality (AR) (Putra & Muhammad, 2021). AR is a technology that combines virtual objects with the real world, thereby providing a more concrete and interactive visualisation (Ganzor, 2021; Hariyono, 2023). In learning, particularly in science, AR-based media can help students understand abstract concepts through more realistic visual representations (Puspita et al., 2026). The application of AR in primary education also creates a more engaging, interactive, and meaningful learning experience, thereby supporting students' understanding of complex concepts through realistic visualisations and

immersive experiences (Tan & Tay, 2022).

Over the past five years, research into the use of Augmented Reality (AR) in primary education has shown significant progress. The findings of Leliavia's (2023) literature review indicate that AR is a relevant innovation in educational media in the era of the Fourth Industrial Revolution, as it is capable of improving learning outcomes and students' ability to construct knowledge through more meaningful learning experiences. In line with these findings, Gutama and Winanto (2025) concluded that the use of AR media has a positive impact on improving students' conceptual understanding and learning motivation, thus having the potential to become an innovative alternative in science education in primary schools. Research by Alfarizi et al. (2024) also confirms that AR is an innovative learning medium suited to the demands of the digital age. Furthermore, a literature review conducted by Siki and Leba (2025) indicates that AR not only enhances students' understanding of scientific concepts but also creates a more enjoyable learning experience. Nevertheless, these various studies

still reveal a gap: there has not yet been significant development of AR media that systematically integrates pedagogical approaches to comprehensively optimise pupils' learning outcomes at primary school level.

In light of this gap, this study proposes the development of interactive learning media based on Augmented Reality (AR), designed to integrate pedagogical approaches tailored to the characteristics and learning needs of primary school pupils. The media developed not only presents interactive 3D visualisations of objects but also incorporates various components that support students' active engagement in the learning process. Consequently, this media is expected to serve as an educational innovation that is not only visually appealing but also effective in enhancing students' conceptual understanding and learning outcomes in primary schools (Resti et al., 2024).

Therefore, this literature review aims to analyse research trends relating to the development of Augmented Reality (AR)-based interactive learning media at primary school level during the period 2022–2026 using a bibliometric analysis

approach. The research data is sourced from the Scopus database, which was selected due to its extensive coverage of scientific publications and its recognition as one of the primary data sources in bibliometric studies (Tong et al., 2025; Bass et al., 2020). By focusing on reputable publications indexed in Scopus at a global level, this study is expected to provide a comprehensive overview of the current developments, trends, and directions of research related to the development of AR-based learning media to support improvements in the learning outcomes of primary school pupils in the future. To guide the systematic review process, several research questions (*Research Questions/RQ*) have been formulated:

(RQ1) What is the distribution of publications on the development of Augmented Reality-based interactive learning media for primary schools between 2022 and 2026, based on year of publication, country, and subject area?

(RQ2) What are the results of the keyword co-occurrence analysis of the literature on the development of Augmented Reality-based interactive

learning media in primary education based on bibliometric mapping?

(RQ3) What are the dominant research themes and emerging trends in the development of Augmented Reality-based interactive learning media for primary education between 2022 and 2026?

The uniqueness of this study lies in its focus on research developments during the 2022–2026 period, which represents a crucial phase in the development and utilisation of Augmented Reality (AR)-based learning materials. Furthermore, this study specifically examines the implementation of AR at primary education level within a global context, using Scopus-indexed publications as its primary data source. This focus distinguishes this study from previous research, which has generally been limited to specific geographical regions, employed diverse methodological approaches, or covered a broader range of educational levels.

B. Research Methods

Bibliometric analysis was used in this study to identify research trends, map the structure scientific knowledge, and trace the

development of a field of study through the analysis of large-scale unstructured scientific data (Donthu et al., 2021). Bibliometric methods are also widely used as a reliable approach to evaluate the impact, productivity, and scientific significance of a study (Szydlowski, 2025). Research data were collected from the Scopus database, which was selected for its extensive coverage of high-quality peer-reviewed scientific publications and its recognitions as a reliable data source in bibliometric studies (Aldhaferi et al., 2026). Furthermore, Scopus offers a more comprehensive coverage of educational literature compared to other databases, making it relevant for supporting the analysis of research developments in the field of education (Irwanto, 2025). The keywords used in this study are as follows (TITLE-ABS-KEY):

("learning media" AND "augmented reality" AND ("elementary school" OR "primary school"))

The search was conducted on 24 March 2026 using the Scopus database. A total of 436 documents were retrieved. Several filters were then applied to ensure the relevance and quality of the data:

- Limited to publications from 2022 to 2026
- Subject area: social sciences
- Document category: article
- Language: English
- Publication stage: final
- Open access

Following the screening process, 37 documents were retained and used as the dataset for this study. These were then analysed using two complementary approaches: descriptive analysis and bibliometric visualisation. Descriptive analysis was conducted to map the distribution of publications by year, country and field of study. This analysis was carried out directly using the Scopus Analyse feature, which provides an overview of research publication patterns. In addition, the VOSviewer software (version 1.6.20.0) was used for bibliometric mapping analysis, as it is recognised as one of the best options for conducting scientific mapping analysis and is highly suitable for bibliometric studies using Scopus data (Eck & Waltman, 2023; Kirby, 2023). This analysis aims to identify dominant research themes, clusters of keywords, and emerging trends within the retrieved documents. In VOSviewer, the analysis is based on

the text of the title and abstract, with a minimum term occurrence threshold set at 10, in accordance with the default parameters recommended by VOSviewer.

C.Result and Discussion

Overview of the Analysis Result

Distribution by Year

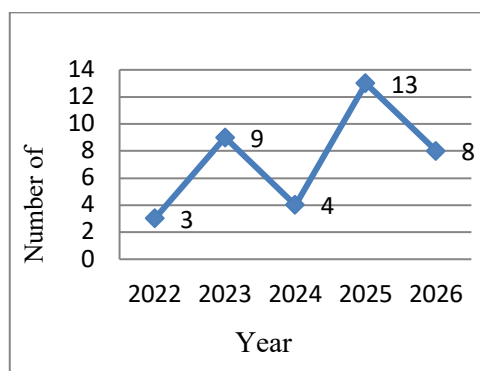


Figure 1. Distribution by Year

The distribution results are shown in Figure 2. Based on the data generated, it can be seen that the number of publications fluctuated during the 2022–2026 period. It began with 3 documents in 2022, followed by 9 in 2023, 4 in 2024, and peaked at 13 publications in 2025. A total of 8 documents were recorded for 2026. This fluctuating pattern indicates that although academic interest in the topic of Augmented Reality (AR) learning media in primary education is quite high, the publication trend is not yet fully stable. This growth pattern suggests that there are still

opportunities to improve the continuity and productivity of research in the future.

Distribusi by Country

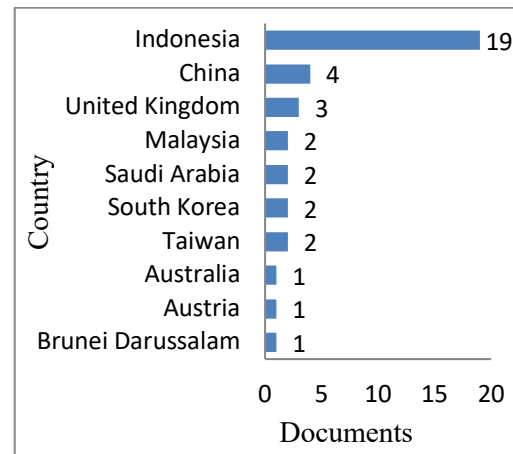


Figure 2 Distribution by Country

The geographical distribution of publications indicates that research into the development of Augmented Reality (AR)-based interactive learning materials for primary education is still dominated by Asian countries. Indonesia is the largest contributor with 19 publications (51.35% of the total documents), followed by China (4 publications) and the United Kingdom (3 publications). Meanwhile, Malaysia, Saudi Arabia, South Korea, and Taiwan each contributed 2 publications, whilst Australia, Austria, and Brunei Darussalam each produced 1 publication. These findings indicate that AR research in primary education remains concentrated in specific

regions and has not yet developed evenly at the global level. The dominance of Asia, particularly Indonesia, is likely influenced by differences in research capacity, levels of international collaboration, and scientific publication policies in each country (Chinchilla et al., 2018; Kwiek, 2021).

Distribution by Subject Area

The distribution by field of study reflects the interdisciplinary nature of research into the development of AR-based interactive learning media in primary education. Among the various fields of study, it is evident that research is dominated by the Social Sciences with 19 publications (50.7%), followed by Computer Science with 7 documents (19.2%), and Psychology, Business, Management, Engineering, Energy, and Environmental Sciences with 2 documents each (4.1%). A relatively small contribution was recorded from Art and Humanities with 1 document. The dominance of the Social Sciences indicates that the topics analysed influence teaching practices, learning outcomes, and classroom dynamics. The involvement of various other fields reflects that research topics are not only examined from a single

perspective but also incorporate approaches from other disciplines to enrich the analysis.

Bibliometrik Analysis Using VOSviewer

Keyword Co-occurrence Analysis

Keyword occurrence analysis was conducted using VOSviewer based on the titles and abstracts of the 37 documents obtained, with a minimum threshold of 10 occurrences per term. Following the manual exclusion of general terms and those of no methodological substance, the analysis produced a network map comprising 12 items organised into three clusters.



Figure 3 Network Visualisation of Keyword Co-occurrence

1. Cluster 1: Implementation of AR in learning.

The first red cluster groups together terms relating to the implementation of AR in learning, student experiences and engagement, empirical studies on the use of AR, and research

focusing on primary school pupils. The main keywords in this group include student, study, augmented reality, research, primary school pupil, and use. Most of the research discusses how AR is used by students and how the technology is applied in the learning process.

2. Cluster 2: The effectiveness of AR technology use.

The second green cluster covers terms related to educational technology, the effectiveness of learning media, and the integration of technology into the educational process. The main keywords in this cluster include education, technology, and effectiveness. Research in this cluster places greater emphasis on evaluating the success of technology use, including AR, in improving the quality of learning.

3. Cluster 3: The impact of AR on learning outcomes.

The third blue group covers terms related to the impact of AR technology use, the effects of AR on learning outcomes, and the context of primary schools. The main keywords in this group include impact, effect, and primary school. Research examines the extent to

which AR influences the achievement, motivation, conceptual understanding, or skills of elementary school.

All cluster relationships indicate that the research is dominated by studies on augmented reality in primary education, focusing on pupils, the effectiveness of learning, and the impact of technology—particularly AR—on learning outcomes.

Dominant Research Themes and Emerging Trends

1. Overlay Visualization

This overlay visualisation shows the temporal distribution of keyword usage, with colours ranging from dark blue or purple (earliest publication year, around 2024.2) to yellow (most recent, around 2024.6). This temporal mapping reveals a clear trend in research over the period 2022–2026.



Figure 4 Overlay Visualization of Keyword Co-occurrence

The keywords with the earliest publication dates, shown in dark purple, include 'student', 'education' and 'effectiveness'. Early research focused more on primary school pupils as research subjects, general aspects of education, and measuring the effectiveness of technology use in learning. In other words, research in the early phase was still focused on whether the use of technology in learning was effective for pupils. As the field developed, the keywords 'technology', 'use', 'effect', and 'study' emerged, signalling that the focus of research had shifted to the use of technology in learning, how technology is applied, and the impact of technology on the learning process. Research now not only measures success but also explores the implementation of technology.

The most recently emerging keywords are highlighted in yellow, including augmented reality, impact, primary school and research. The latest research focuses on the use and impact of AR on learning processes and outcomes in primary schools, as well as empirical research on the

implementation of AR. The keywords "augmented reality", "impact" and "primary school" are considered research hotspots or emerging research opportunities.

2. Density Visualization

The density visualisation provides a clearer picture of the intensity and centrality of the research themes previously identified in the overlay network visualisation.

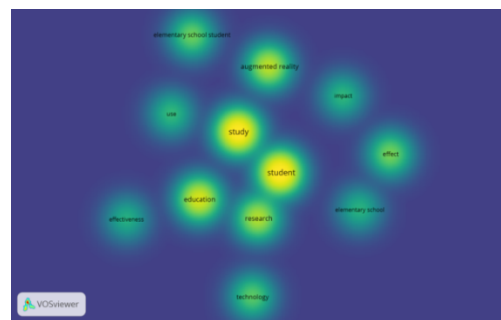


Figure 5. Density Visualization of Keyword Co-occurrence

The figure shows that the keywords in the lightest yellow zone have the highest density, reflecting a high frequency of occurrence and strong links to other keywords. The keywords dominating this zone are 'study', 'student' and 'augmented reality'. These findings indicate that the primary focus of the research lies in the study of the use of Augmented Reality to support the learning process and students'

learning experiences in the field of education. The concentration of yellow colour on these three keywords indicates that these themes constitute the core research themes within the analysed research landscape.

Meanwhile, the green zone represents keywords with a moderate density, such as technology, effect, impact, and use. These keywords serve as supporting themes that broaden the discussion regarding the implementation and impact of Augmented Reality in the context of primary education. Overall, this visualisation pattern indicates that current research trends are dominated by studies focusing on the effectiveness and utilisation of Augmented Reality in enhancing the quality of the learning experience and student learning outcomes in primary schools.

Discussion

The findings of this study provide important insights into current developments and research directions regarding the development of Augmented Reality (AR)-based interactive learning materials to improve learning outcomes for primary

school pupils. Firstly, the consistent increase in the number of publications, particularly the significant surge during the 2023–2026 period, indicates a high level of academic interest in the use of AR as an innovation in learning. This trend reflects a strong response to the rapid development of digital technology and its potential to support the learning process at primary education level. Nevertheless, the distribution of publications, which remains concentrated in Asian countries, indicates that research on AR in primary education has not yet developed evenly at a global level. This situation highlights a vast opportunity to expand international research and collaboration to enrich the development and implementation of AR within the context of primary education across various countries.

Second, the results of the bibliometric mapping indicate that research in this field is divided into three main, interrelated clusters. The first cluster focuses on the implementation of Augmented Reality (AR) in the learning process and the resulting benefits for primary school pupils. The second cluster highlights the effectiveness of AR in improving the quality of learning, suggesting that

the successful utilisation of AR depends not only on technological aspects but also requires a structured pedagogical approach and teachers' readiness to integrate it into their teaching. Meanwhile, the third cluster focuses on the impact of AR use in primary schools. The emergence of these clusters indicates the development of new research directions that have the potential to become a key focus of AR studies in primary education in the future.

Third, a temporal analysis using overlay visualisation reveals a shift in the focus of research over the years. Studies that initially centred on the fundamental aspects of Augmented Reality (AR), such as technological implementation and accuracy, subsequently shifted towards more complex issues, including learning motivation, learning contexts, and pedagogical approaches. This shift indicates that the field of AR research is maturing and beginning to accommodate the complexity of its application across various primary education settings. This finding aligns with previous research emphasising the importance of considering the developmental characteristics of primary school

pupils in the development of AR-based learning media. Furthermore, the research output remains dominated by contributions from institutions in the Asian region. Whilst this reflects the high level of research productivity in that region, it also highlights the need for more diverse and comprehensive studies within a cross-cultural context. The lack of contributions from countries such as Australia, Austria, and Brunei Darussalam indicates that AR research in primary education has not yet received equal global attention, which is likely influenced by differences in curricula, the availability of technology, and research priorities in each region.

The findings of this study successfully answer the three research questions posed. Firstly, the trend in publications regarding the development of Augmented Reality (AR)-based interactive learning media to improve the learning outcomes of primary school pupils shows an increase that tends to fluctuate over the period 2022–2026. Indonesia is recorded as the largest contributor to publications, whilst the Social Sciences are the most dominant discipline in this study. Secondly, an

analysis of keyword co-occurrence reveals three main research themes, namely the implementation of AR in learning, the effectiveness of using AR technology, and its impact on student learning outcomes. Thirdly, the results of overlay and density visualisations indicate a shift in research focus towards the utilisation of technology in learning and the application of AR in the context of primary education. Overall, the findings of this study confirm that research on AR in primary education continues to evolve and still holds great potential for further exploration across various educational contexts and environments in the future.

D. Conclusion

This study maps research trends regarding the development of Augmented Reality (AR)-based interactive learning media to improve the learning outcomes of primary school pupils, based on 37 Scopus-indexed publications from 2022 to 2026. The analysis reveals an increase in the number of publications, particularly during the 2023–2025 period, with Indonesia as the largest contributor, followed by China and the United Kingdom. The study is

dominated by the fields of Social Sciences and Computer Science, reflecting the interdisciplinary nature of AR research in primary education. Keyword analysis identified three main research focuses: the implementation of AR in learning, the effectiveness of AR use, and the impact of AR on student learning outcomes. Overlay visualisation indicates that topics related to Augmented Reality constitute a continuously evolving research area, whilst density visualisation confirms that evaluating the use of AR to enhance student learning experiences and outcomes is the most dominant theme. Overall, these findings indicate that AR is gaining increasing attention as an educational innovation in primary schools and still holds significant potential for further development. Future research should expand its scope to include diverse geographical and cultural contexts and explore the long-term impact of AR implementation on pupils' development and learning outcomes.

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