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Bibliometric Mapping of Augmented Reality in Indonesian Education: A Decade of Trends and Insights

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ABSTRACT

This study aims to map the development of Augmented Reality (AR) research in Indonesian education using a bibliometric approach. A total of 118 documents published between 2014 and 2024 were retrieved from the Scopus database and analyzed using VOSviewer and R programming tools. The analysis identified key trends, research focuses, and emerging themes in the field. Results showed a significant annual publication growth rate of 27.91%, with increasing collaboration among national and international scholars. The most prominent research themes centered around AR as a learning medium, with emerging topics including teacher readiness, experiential learning, computational thinking, gamification, and digital literacy. These trends suggest a shift from technological novelty toward pedagogical integration and digital competence in educational practices. The study offers practical insights for educators, institutions, and policymakers in designing sustainable AR implementation strategies that align with Indonesia's education context. Recommended actions include strengthening teacher training in digital pedagogy, developing localized AR content, and establishing supportive infrastructure policies. Limitations include the exclusive use of the Scopus database, which may have excluded local or non-indexed literature, potentially affecting the comprehensiveness of the results. Future studies should incorporate broader data sources and qualitative approaches to explore AR adoption at the classroom level.

1. Introduction

The increasing adoption of immersive technologies such as Augmented Reality (AR) and Virtual Reality (VR) in education reflects a paradigm shift toward more interactive, student-centered, and visual learning experiences [1], [2], [3]. These technologies are recognized for their potential to enhance learning motivation, engagement, and comprehension particularly for complex or abstract concepts by simulating real-world contexts. Globally, AR/VR is being integrated into curricula as part of digital transformation initiatives in countries such as South Korea, Japan, and Singapore [4].

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Despite this global trend, the integration of AR in Indonesia's formal education system remains limited.

In response, the Indonesian government has introduced various digitalization policies, including the development of learning platforms, teacher training programs, and infrastructure enhancement [5], [6], such as the development of digital platforms, teacher training, and strengthening technology infrastructure. These efforts reflect a commitment to creating a learning ecosystem that is responsive to technological developments. In this context, Augmented Reality (AR) has been introduced as one of the alternative learning media that can increase the attractiveness and effectiveness of material delivery [7], [8], [9], [10], [11]. Some higher education institutions and schools have started to carry out limited experiments in the application of AR in the classroom. This step shows a great opportunity to develop technology-based learning media that is more immersive and contextual.

Limited facilities and infrastructure remain a major challenge in the digital transformation of education in Indonesia [12]. Many schools, especially in remote areas, do not have adequate access to technological devices such as computers, tablets, or stable internet connections [13]. This condition causes a gap in the implementation of digital-based learning innovations, including the utilization of Augmented Reality (AR) [14]. In addition, the lack of technical support and device maintenance also hinders the sustainability of technology use in the teaching and learning process. This shows that infrastructure readiness is a crucial factor in the successful implementation of AR-based learning media in Indonesia's educational environment.

The limited utilization of Augmented Reality (AR) technology in schools and universities across Indonesia indicates that this innovation has yet to be fully integrated into the formal education system. AR usage remains confined to pilot projects or small-scale research initiatives that have not reached a broader implementation level [15], [16]. In fact, this technology holds significant potential to support visual, simulation-based, and interactive learning across various subjects such as biology, physics, history, and geography. The low adoption rate may stem from educators' limited understanding of AR's benefits, a lack of resources, and the absence of regulations or curricula that systematically promote AR integration. This situation highlights the need for a national strategy and a structured approach to encourage the adoption of AR as part of the future of learning media [13].

Teacher readiness in adopting new technologies represents one of the main barriers to integrating digital innovations into education [17]. Many teachers still lack both the technical and pedagogical skills required to operate and integrate technologies such as Augmented Reality into their teaching practices. These limitations include insufficient understanding of AR applications, weak planning of technology-enhanced lessons, and limited capacity to assess their effectiveness in the classroom. As a result, teaching processes tend to remain conventional and fail to harness the potential of interactive media, leading to reduced student interest and engagement especially when dealing with abstract or complex topics [18]. Therefore, strengthening teacher capacity is key to optimizing the benefits of emerging technologies in the educational landscape.

The scarcity of local research on the effectiveness of Augmented Reality in the Indonesian educational context presents a critical gap that requires urgent attention [19], [20]. Most of the available studies originate from abroad, with different socio-cultural and infrastructural contexts, limiting their applicability to Indonesian settings. Moreover, the lack of research that specifically examines AR implementation based on infrastructure readiness and educators' digital competencies further widens the gap between the technology's potential and its practical application. Understanding the technical preparedness and human resource capacity is essential for designing targeted implementation strategies. Without adequate local data and analysis, AR-based educational policies and innovations risk becoming unsustainable. Hence, context-specific research in Indonesia is essential to produce practical and realistic recommendations.

The diagram in Fig. 1 illustrates the most relevant journal sources related to Augmented Reality (AR) research in education. It shows that the majority of publications are found in the International Journal of Information and Education, with 16 documents far surpassing other sources. This confirms

the dominance of international literature in this field. Meanwhile, other journals such as TEM Journal, Jurnal Pendidikan IPA Indonesia, and the International Journal of Emerging Technologies in Learning contributed only 3 to 7 documents each. Notably, only a few publications are from Indonesian journals, such as Jurnal Pendidikan IPA Indonesia, reinforcing earlier findings about the lack of locally based AR research in education. The dominance of international journals further underscores the urgent need for Indonesia-specific studies to ensure relevance to national needs particularly in mapping the country's infrastructure readiness and educators' digital competencies.

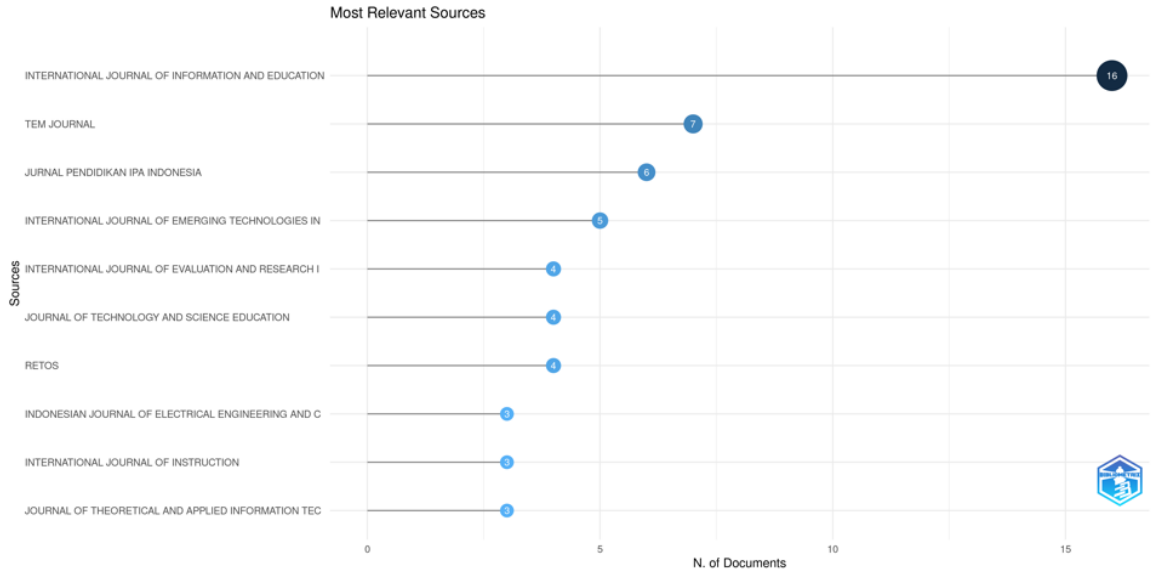

Fig. 1. Top AR Publication Sources

A new approach that integrates teacher readiness, gamification, computational thinking, and digital literacy within the context of Augmented Reality (AR) presents a significant opportunity to develop a more adaptive and relevant learning model aligned with 21st-century educational demands. These four elements are interconnected in shaping a technology-based learning ecosystem that is both effective and engaging. Teacher readiness ensures that educators possess the competencies to adopt and apply AR in the classroom; gamification enhances student motivation and engagement; computational thinking fosters logical reasoning and problem-solving skills essential in the digital era; and digital literacy provides the foundational capacity for all educational stakeholders to access and utilize technology responsibly and productively [21]. Context-specific research within Indonesia is urgently needed to explore how these four dimensions can be practically integrated into everyday learning. Such an investigation would allow for a more realistic mapping of AR implementation challenges and inform solutions that are both contextual and applicable. This study addresses the following research questions:

Q1: What are the publication trends and patterns in AR-related educational research in Indonesia between 2014 and 2024?

Q2: Which emerging concepts—such as teacher readiness, gamification, computational thinking, and digital literacy—are shaping the current research direction?

This study contributes to map the development of Augmented Reality (AR) research in Indonesian education using a bibliometric approach. The study offers practical insights for educators, institutions, and policymakers in designing sustainable AR implementation strategies that align with Indonesia’s education context. Recommended actions include strengthening teacher training in digital pedagogy, developing localized AR content, and establishing supportive infrastructure policies.

2. Method

This study employs a bibliometric research design to systematically analyze academic publications related to the use of Augmented Reality (AR) in education, with a particular focus on studies relevant to the Indonesian context [22], [23]. The objective is to identify major trends, research focuses, and the development of key concepts especially those associated with teacher readiness, gamification, computational thinking, and digital literacy [24]. Data were retrieved from the Scopus database using a predefined set of keywords, covering the publication period from 2014 to 2024. The selection process applied inclusion and exclusion criteria to ensure the relevance of publications, emphasizing articles that address both conceptual and practical aspects of AR implementation in education. Analysis was conducted on titles, abstracts, and author-defined keywords to trace conceptual development and the educational potential of AR. This approach provides a transparent and replicable framework for generating data-driven insights and recommendations for the implementation of AR in Indonesian educational environments.

Fig. 2 presents the PRISMA-based flow diagram illustrating the document identification and selection process for the bibliometric analysis. The study focused on the topic "Augmented Reality in Education in Indonesia," with data retrieved from the Scopus database within the time span of 2014 to 2024. The search keywords included terms such as "augmented reality" combined with "educat*", "school*", and "learn*". The data collection was conducted on July 1, 2025, yielding a total of 4,339 non-duplicate documents. During the screening stage, documents were filtered based on the authors' affiliations, limiting results to publications affiliated with institutions in Indonesia. This process narrowed the dataset to 4,281 publications. In the eligibility stage, titles and abstracts were reviewed to ensure alignment with the research topic, and no further documents were excluded. Consequently, a total of 118 documents were included in the final bibliometric analysis. This flow diagram reflects a systematic and targeted selection process to ensure both geographical focus and thematic relevance.

The inclusion and exclusion process were systematically implemented to ensure that only relevant documents were analyzed. Inclusion criteria focused on publications that specifically discussed the use of Augmented Reality (AR) in educational contexts and were affiliated with Indonesian institutions. The types of publications analyzed included journal articles and literature reviews published between 2014 and 2024. Meanwhile, exclusion criteria were applied to documents unrelated to education, such as AR studies in the fields of medicine, engineering, or pure entertainment. Documents that did not contain core keywords in their titles, abstracts, or author-defined keywords were also excluded. This approach ensured that selected publications aligned with the study's aim to explore research trends and the potential of AR in the Indonesian education sector.

Inclusion criteria were applied are

1. Publications focused specifically on the application of AR in education;
2. At least one author was affiliated with an Indonesian institution;
3. Article types included peer-reviewed journal articles and literature reviews;
4. Published in English.

Exclusion criteria are

1. Articles that discussed AR in non-educational domains (e.g., medicine, engineering, entertainment);
2. Articles that lacked relevant keywords or did not clearly discuss AR in education;
3. Editorials, conference abstracts without full papers, and opinion pieces;
4. After screening, 4,281 documents were excluded, and 118 documents were retained for analysis.

Data analysis in this study was conducted using two primary tools. VOSviewer was employed to analyze research focuses and keyword novelty within the dataset. This analysis included mapping the co-occurrence of frequently appearing keywords in titles and abstracts, as well as visualizing their network relationships. Through VOSviewer, dominant research themes and emerging concepts were identified, reflecting shifts and expansions in AR-related educational research. This approach allows

for a deeper understanding of the conceptual focus and the evolving dynamics of the field. To ensure relevance to the Indonesian educational context.

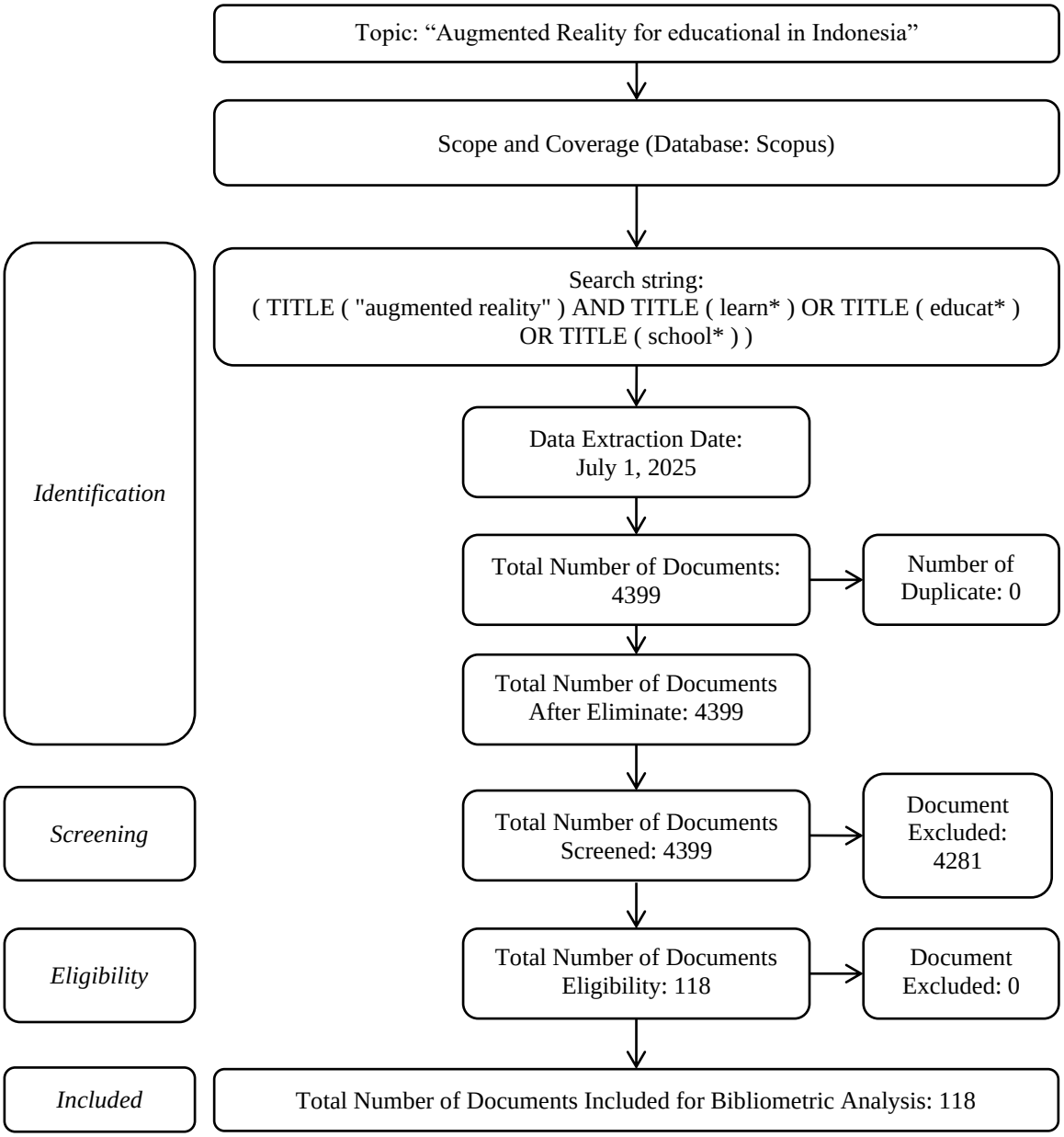

Fig. 2. PRISMA Method for Document Selection

3. Results and Discussion

3.1. Main Information

Research Main Information is shown in Fig. 3. Research on Augmented Reality (AR) in education has shown rapid growth over the past decade. This is evidenced by the publication span from 2014 to 2024, with an annual growth rate reaching 27.91%. This figure highlights the increasing interest among researchers in applying AR to the field of education, in parallel with the acceleration of digital technology development.

During this period, a total of 118 scientific documents were published across 64 different sources, including journals and conference proceedings. These publications involved 494 authors, with an

average of approximately 4.85 authors per document indicating a high level of scholarly collaboration. Notably, only 3 documents were authored by a single researcher, reinforcing the observation that AR research in education is predominantly conducted through collaborative efforts.

Beyond national collaboration, the field also reflects a strong degree of international cooperation. Approximately 28.81% of the publications were the result of cross-country collaborations, indicating that the application of AR in education is a topic of global concern. This presents a promising opportunity to foster international research networks that enable the exchange of experiences and the enrichment of perspectives.

In terms of content, these studies cited a total of 5,397 references and utilized 332 unique keywords, reflecting the breadth and depth of the literature employed. Interestingly, the average age of the documents is only 2.19 years, suggesting that the discourse on AR in education remains relatively new and dynamic. On average, each document has received 7 citations, indicating a meaningful contribution to the advancement of knowledge in this emerging field.

Fig. 3. Main Information

3.2. Publication Trends and Growth

The results reveal a significant increase in publications on Augmented Reality (AR) in Indonesian education from 2014 to 2024. The number of publications grew from only 3 documents in 2014 to 23 in 2023, with an average annual growth rate of 27.91% (Fig. 3). This indicates growing scholarly interest in AR, especially after the COVID-19 pandemic, which accelerated the push for digital innovation in education. The publication spike in the last five years aligns with national digitalization programs and the integration of technology in higher education. This trend shows that AR is increasingly seen as a promising learning tool in Indonesian classrooms. However, the slow start in earlier years reflects institutional hesitation and infrastructural barriers that still persist, particularly outside urban centers.

3.3. Authors, Institutions, and Collaboration Patterns

A total of 494 authors contributed to the 118 publications analyzed, with an average of 4.85 authors per article, indicating a high level of collaboration. Only 3 articles were authored individually, reinforcing the collaborative nature of AR research. Table 1 demonstrates that research on Augmented Reality (AR) in Indonesian education is highly concentrated within a small number of leading institutions, particularly those with strong backgrounds in teacher education and educational research

Table 1. Analysis of institutional affiliation showed that the most active institutions were

Rank	Institution	Number of Publications
1	Universitas Negeri Yogyakarta (UNY)	14
2	Universitas Pendidikan Indonesia	12
3	Universitas Negeri Malang	9
4	Universitas Negeri Semarang (UNNES)	8
5	Universitas Gadjah Mada	6

Table 2 provides a holistic picture of the direction and priorities of AR research in Indonesian education. The five main clusters show that research has moved from technical/technological aspects to pedagogical issues, human resource development, and infrastructure readiness. These results also reinforce the importance of an implementation strategy that focuses not only on device procurement, but also training, content development, and equal access.

Table 2. Conceptual Focus and Thematic Clustering

Cluster	Dominant Keywords	Thematic Focus
1	learning media, mobile learning, geometry	AR as a content delivery and visualization tool
2	teacher readiness, training, pedagogy	Educator capacity and readiness
3	gamification, student motivation, engagement	AR in game-based learning environments
4	computational thinking, logic, problem-solving	Higher-order thinking and digital skills
5	digital literacy, online learning, blended learning	Infrastructure and technology access

3.4. Research Focus Analysis

The analysis of research focus using VOSviewer aims to identify the key themes within the body of literature on Augmented Reality (AR) in education in Indonesia. By mapping the relationships among keywords, this analysis helps to reveal the direction, concentration, and dominant trends in the dataset. The bibliometric network visualization indicates that "learning media" emerges as a central theme, strongly interconnected with various concepts and educational technologies (Fig. 4). This is evident from its close association with keywords such as "mobile learning", "augmented reality (AR)", "education", and "self-regulated learning", suggesting that researchers have been highly focused on how AR and mobile platforms can be effectively integrated as learning tools to meet diverse educational needs.

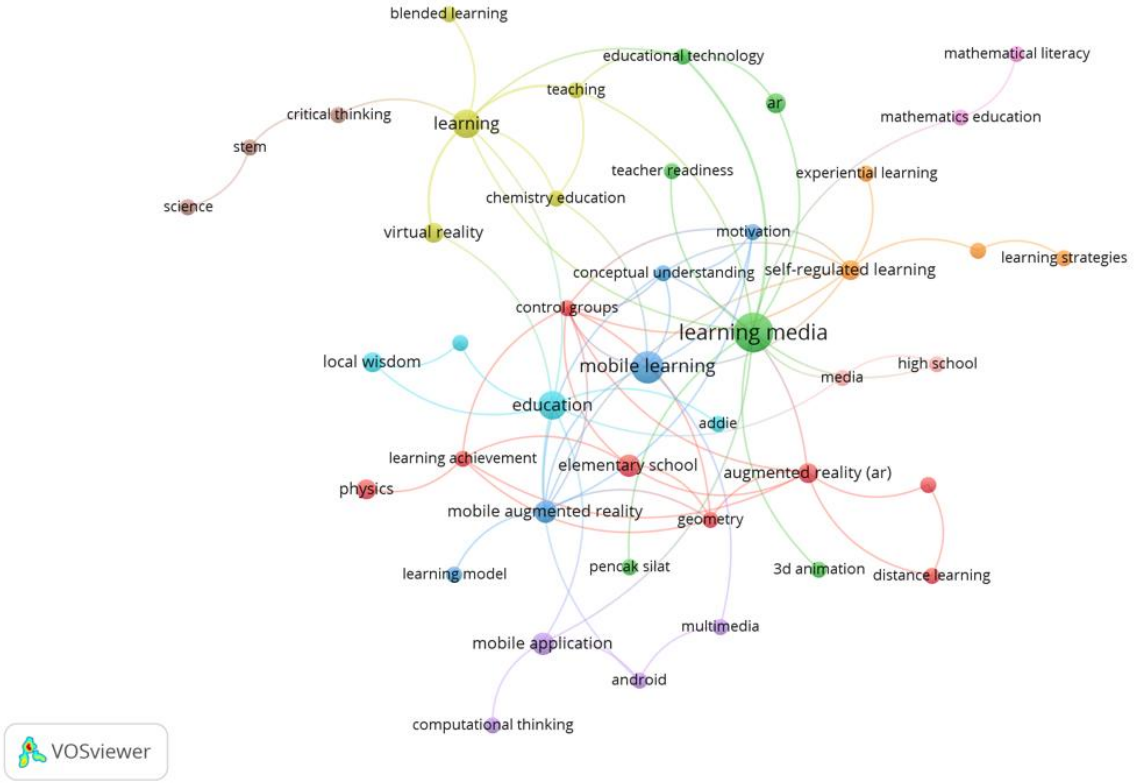

Fig. 4. Research Focus Analysis

In addition, the network illustrates strong connections between AR and concepts such as "3D animation", "geometry", and "distance learning", reflecting a tendency to apply AR in specific content

areas and in learning models that emphasize visualization and remote education. Notably, the emergence of keywords such as “virtual reality”, “blended learning”, and “teacher readiness” indicates that researchers are not solely concerned with technological adoption, but are also attentive to pedagogical approaches and teacher preparedness for the successful implementation of AR. Furthermore, the presence of keyword clusters such as “local wisdom”, “pencak silat”, and “elementary school” highlights a research direction that seeks to embed AR applications within the context of local culture and primary education.

Overall, this analysis confirms a growing trend among Indonesian researchers to explore AR not merely as a technological tool, but as an integral component of a broader educational innovation ecosystem. This includes efforts to enhance learning engagement, conceptual understanding, and the development of 21st-century skills.

3.5. Keyword Novelty

The keyword novelty analysis aims to identify emerging terms that have recently appeared in the field of Augmented Reality (AR) research for education in Indonesia. These findings provide insights into the current direction of research development in the country and highlight topics that are beginning to attract increased scholarly attention (Fig. 5).

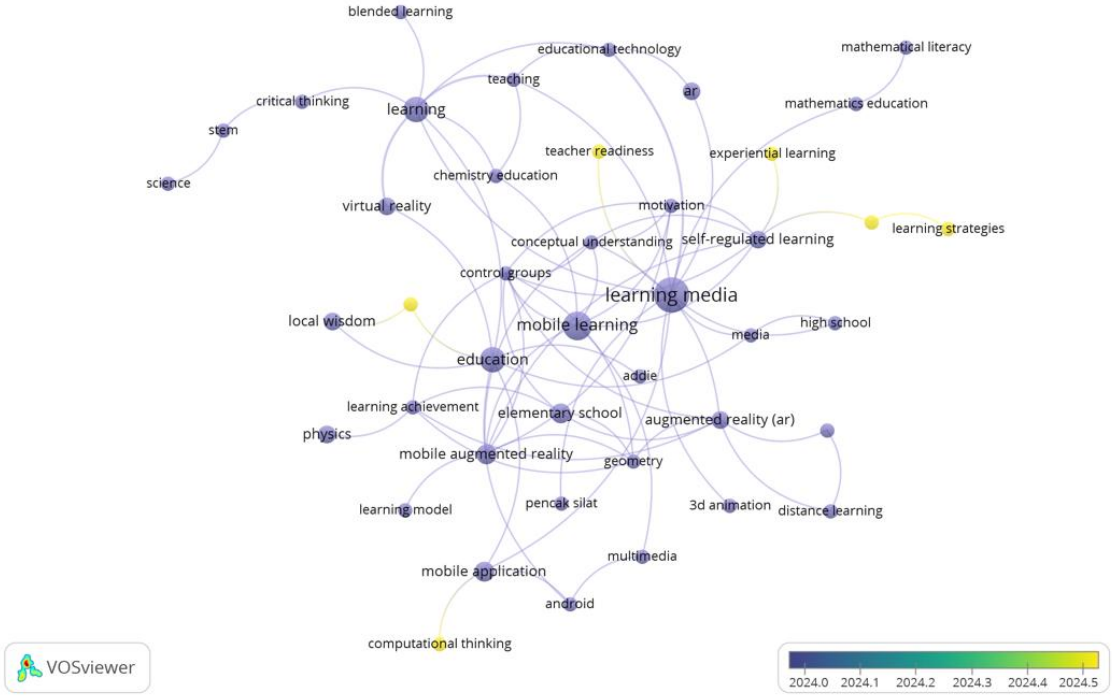

Fig. 5. Keyword Novelty

In the VOSviewer visualization, keywords highlighted in yellow represent relatively new themes within this domain. The yellow color indicates that these keywords have only started to appear in recent years and have not yet been extensively explored in the existing body of literature. This layer of analysis allows researchers and policymakers to recognize evolving interests and identify opportunities for future investigation into under-researched but potentially impactful areas.

The keyword novelty analysis using VOSviewer visualization reveals several emerging topics that are gaining attention in research on Augmented Reality (AR) in education in Indonesia. The yellow color on the bibliometric map indicates keywords that have appeared relatively recently in publications over the past few years. Among these emerging terms, several stand out as particularly noteworthy: “teacher readiness”, “experiential learning”, “computational thinking”, “gamification”, and “digital literacy”.

The appearance of the keyword “teacher readiness” underscores the growing recognition of educator preparedness as a crucial factor in the successful adoption and implementation of AR technologies in classrooms [25]. This suggests a shifting research focus toward teachers' competencies and their central role in digital integration. Additionally, the keyword “experiential learning” reflects increased interest in experience-based pedagogical approaches, which align naturally with AR's capacity to facilitate interactive virtual simulations and hands-on learning experiences [26].

The emergence of “computational thinking” highlights a rising effort to connect AR with the development of higher-order thinking skills, particularly logical reasoning and problem-solving skills essential [27]. Meanwhile, the keyword “gamification” signals a trend toward incorporating game elements into AR-enhanced learning environments to boost student motivation and engagement [28]. Lastly, “digital literacy” emphasizes researchers’ growing concern with equipping both teachers and students with the foundational skills needed to effectively and responsibly navigate AR technologies [29], [30], [31].

These emerging keywords not only reveal the evolving direction of AR research in education but also present new opportunities for the development of contextualized, engaging learning models that support digital literacy and higher-order thinking skills in Indonesia. These findings serve as a valuable recommendation for future researchers seeking to align AR-based educational studies with real-world classroom needs and national education goals.

4. Discussion

This study provides a comprehensive bibliometric analysis of Augmented Reality (AR) research in the Indonesian education context over the past decade (2014–2024). The findings reveal a notable increase in publication output, with an average annual growth rate of 27.91%, indicating rising academic interest in AR as a tool for educational innovation. However, this growth remains largely driven by international literature, with limited representation of Indonesia-based studies.

The research focus has gradually shifted from AR as a novel technology to its integration within broader pedagogical frameworks. Emerging themes such as teacher readiness, experiential learning, computational thinking, gamification, and digital literacy highlight the evolving discourse from technological adoption to instructional design and classroom implementation. These themes suggest that for AR to be effectively adopted in Indonesian classrooms, strategies must extend beyond hardware provision to include teacher training, curriculum alignment, and institutional support.

Based on the findings, we recommend the following actionable steps:

1. For educators: Invest in professional development programs focused on digital pedagogy and AR integration;
2. For institutions: Support interdisciplinary collaborations between education, technology, and instructional design departments to develop contextual AR content;
3. For policymakers: Develop national guidelines and funding schemes that encourage scalable, equitable adoption of AR in both urban and rural schools.

Despite its strengths, this study has several limitations. First, the use of only the Scopus database may have excluded relevant local or non-indexed publications, leading to potential publication bias. Second, the focus on title-based keyword searches may have overlooked studies where AR was discussed more broadly in the full text. Third, the exclusion of gray literature and non-English/Bahasa publications limits the scope of cultural and policy-related insights.

By providing data-driven insights and contextual recommendations, this study aims to support the development of scalable and sustainable AR strategies in Indonesian education, advancing both theory and practice in digital learning innovation.

5. Conclusion

This study reveals a significant increase in research on Augmented Reality (AR) in Indonesian education over the past decade, although the field is still predominantly shaped by international literature. The focus of research has shifted from AR as a novel technology to its integration within broader pedagogical frameworks. Emerging themes such as teacher readiness, experiential learning, computational thinking, gamification, and digital literacy reflect an evolving discourse from technological adoption toward instructional design and classroom implementation.

The bibliometric analysis underscores the importance of cross-disciplinary collaboration, enhanced teacher training, the development of contextual AR content, and improved digital infrastructure to support sustainable AR implementation in Indonesian educational environments. Furthermore, the limited availability of local data and context-specific studies highlights the urgent need for more inclusive and methodologically diverse research in this area.

Future research should address these limitations by incorporating other databases (e.g., Google Scholar, Garuda, DOAJ), conducting qualitative or mixed-methods investigations to capture classroom-level AR implementation, and exploring regional differences in infrastructure, teacher readiness, and policy alignment. Additionally, longitudinal studies are needed to assess the sustained impact of AR on student outcomes and teacher practices in the Indonesian context.

Declaration

Supplementary Materials: Supplementary materials of this study include the full dataset retrieved from Scopus and visualizations generated using VOSviewer and Program R.

Author Contributions: RNG: Conceptualization, Writing - Initial Draft, Editing and Visualization, Methodology and Review & Editing, MFFA & NGAAR: Conceptualization, Formal analysis, Methodology and Review & Editing; SR: Validation and Monitoring. All authors have read and approved the published version of the manuscript.

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