Augmented Reality in Mathematics Education: A Bibliometric Analysis

Hodiyanto[1]*, Kwajalynne Costales Alegre[2]

[1]Mathematics Education, Faculty of Mathematics, Natural Sciences, and Technology, Universitas PGRI Pontianak, Ampera Street No. 88, Pontianak, West Kalimantan, Indonesia
[2]Mathematics Education, President Ramon MAGSAYSAY State University, Philippines
*Corresponding author: hhodiyanto@gmail.com

Abstract. Augmented reality (AR) has emerged as a significant technology-enhanced approach in mathematics education. Despite the growing volume of publications, a comprehensive bibliometric mapping of AR research in mathematics education has yet to be published. This study conducts a bibliometric analysis to explore the trends, key contributors, and future directions of AR research in mathematics education from 2016 to 2025. Data were retrieved from the Scopus database and analysed using VOSviewer software. A total of 190 open-access journal articles published in English were selected after three stages of filtering. The results reveal substantial publication growth, particularly from 2020 onward, with a sharp increase in 2024 and 2025 (46 articles each year). Indonesia is the most productive country (40 articles), followed by Malaysia (30) and the United States (20). Lavicza Z. from Johannes Kepler University Linz is the most productive author (6 articles). Keyword co-occurrence analysis identified five research clusters: AR technology and student learning, STEM education, mathematics and educational technology, geometry and teaching, and mobile AR. Emerging and underexplored themes include computational thinking, spatial ability, game-based learning, and higher education contexts. These findings provide a comprehensive map of the field and a foundation for future research directions.
Keywords: Augmented Reality, Bibliometric, Mathematics Education, STEM, VOSviewer

How to cite (in APA style):
Hodiyanto, & Alegre, K.C. (2026). Augmented Reality in Mathematics Education: A Bibliometric Analysis. *Proceeding of IJC-MaSTEd*, 1(1), 134-146.
Copyright © 2026 Auhors.
DOI: https://doi.org/10.31571/ijcmasted.v1i1.1137

1. Introduction

The integration of technology in mathematics education has been widely studied over the past two decades, with augmented reality (AR) emerging as one of the most promising innovations (Akçayır & Akçayır, 2017; Cai et al., 2021). AR technology overlays digital information — including three-dimensional objects, animations, and interactive elements — onto the physical world, creating a hybrid learning environment that enhances students' spatial reasoning and conceptual understanding of abstract mathematical ideas (Bujak et al., 2013; Nincarean et al., 2013; Chang et al., 2022).

The importance of AR in mathematics education lies in the inherently abstract nature of many mathematical concepts. Students frequently struggle to visualise geometric transformations, three-dimensional figures, and calculus concepts (Kaufmann & Schmalstieg, 2003). AR tools can bridge this gap by making abstract concepts concrete and interactive (Yuen et al., 2011; Bulut & Borromeo Ferri, 2023). Numerous studies have demonstrated that AR-based learning positively influences student motivation, engagement, and achievement in mathematics (Ahmad & Junaini, 2020; Cai et al., 2021; Cetintav & Yilmaz, 2023).

Bibliometric analysis is a well-established quantitative method for mapping the intellectual structure and developmental trends of a research domain (Donthu et al., 2021; Ellegaard & Wallin, 2015). It identifies the most influential publications, authors, institutions, and countries, as well as the thematic evolution of a discipline over time (Zupic & Čater, 2015). Bibliometric analyses have been conducted across various subfields of mathematics education, including realistic mathematics education (Phan et al., 2022), mathematical problem-solving (Suseelan et al., 2022), mathematical abstraction (Hodiyanto et al., 2025), and flipped classrooms (Kadarisma et al., 2024). However, a bibliometric analysis specifically focused on AR in mathematics education has not yet been published.

This study addresses that gap through a systematic bibliometric analysis of AR research in mathematics education using the Scopus database for the period 2016–2025. The specific research aims are: (1) to identify the most productive journals, authors, institutions, and countries; (2) to explore the collaborative networks among contributing countries; and (3) to map keyword trends and identify emerging research themes. The findings provide a comprehensive overview of the field and guidance for future research.

2. Method

2.1. Study Design

This study employed bibliometric analysis as its research design — a quantitative method for evaluating published literature by identifying patterns in authorship, citation, and collaboration within a research domain (Ellegaard & Wallin, 2015; Hallinger & Kovačević, 2019). The systematic mapping procedure comprised five phases: research design, bibliometric data compilation, analysis, visualisation, and interpretation (Börner et al., 2003; Zupic & Čater, 2015).

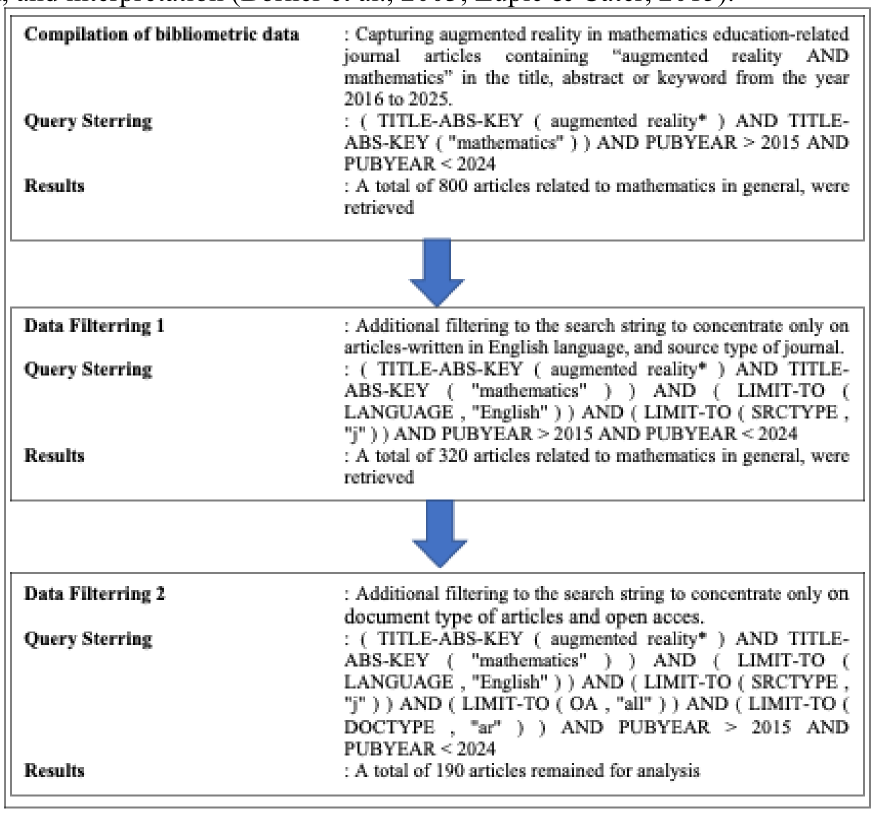

Figure 1. Flowchart of Data Collection and Search Strategy

2.2. Compilation of Bibliometric Data

Data were retrieved from the Scopus database, selected because its subject coverage is approximately 70% wider than other major databases (Ha et al., 2020). The data collection followed three filtering stages, as summarised in Figure 1. The initial query retrieved 800 articles related to mathematics and augmented reality published from 2016 to 2025. The second stage applied filters for English-language journal articles, reducing the dataset to 320 articles. The third stage further restricted the dataset to open-access journal articles, yielding a final sample of 190 articles for analysis.

2.3. Analysis and Visualisation

The Scopus built-in analytics tool generated descriptive statistics on publication growth, contributing journals, authors, institutions, and countries. VOSviewer (version 1.6.20) was used for keyword co-occurrence analysis and network, overlay, and density visualisations (Van Eck & Waltman, 2010). The overlay visualisation displays the average publication year of each keyword (brighter = more recent), identifying emerging themes. The density visualisation indicates research volume (brighter = more studies), revealing underexplored areas that offer opportunities for future investigation.

3. Results and Discussion

3.1. General Information and Growth Trends

A total of 190 open-access journal articles on AR in mathematics education were identified in the Scopus database for 2016–2025 (Figure 2). Publication output was modest from 2016 to 2019, beginning with only 1 article in 2016 and reaching 6 articles in both 2017 and 2018. Moderate growth followed from 2020 to 2023, rising from 15 articles in 2020 to 24 in 2023. The most dramatic increase occurred in 2024 and 2025, each recording 46 articles — the highest annual output in the dataset — demonstrating a sharp acceleration of research interest in AR applications for mathematics education. This exponential growth mirrors broader trends in educational technology research, particularly following the COVID-19 pandemic, which intensified demand for technology-mediated learning solutions and accelerated the adoption of immersive digital tools, including AR, across educational contexts (Cai et al., 2021; Adedoyin & Soykan, 2023). The growing accessibility of AR development tools — including Unity, Vuforia, and GeoGebra AR — and the proliferation of smartphones capable of running AR applications have also contributed to this expansion (Koumpouros, 2024). A broader bibliometric analysis of AR in education by Singh et al. (2024) similarly identified a steep growth trajectory from 2020 onward, corroborating the trend observed in the present study.

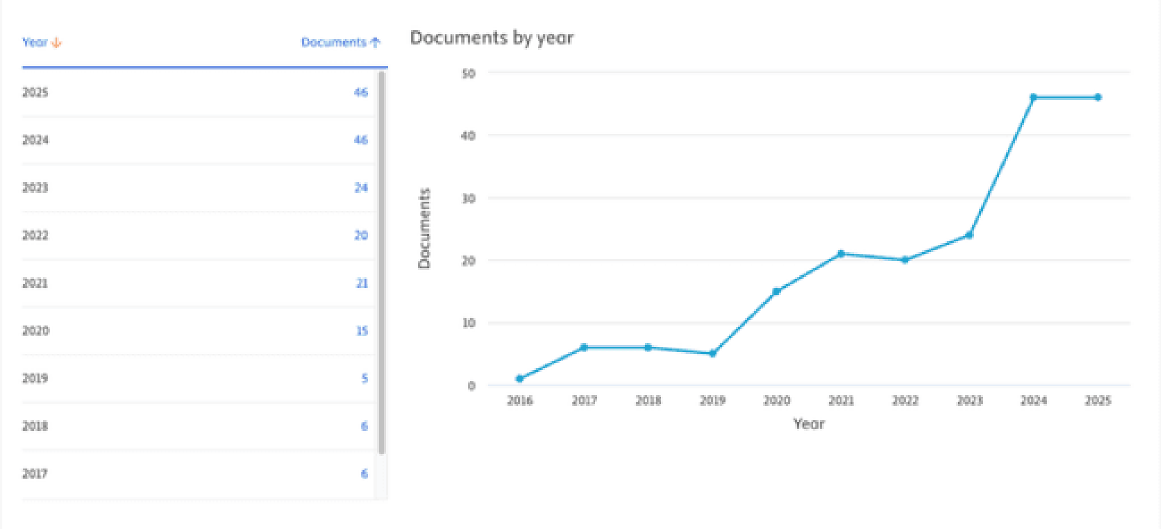

Figure 2. Number of Publications per Year (2016–2025)

3.2. Contribution by Journals

The 190 articles were distributed across numerous journal sources. Figure 3 presents the top contributing journals, and Table 1 provides detailed bibliometric indicators for the top five.

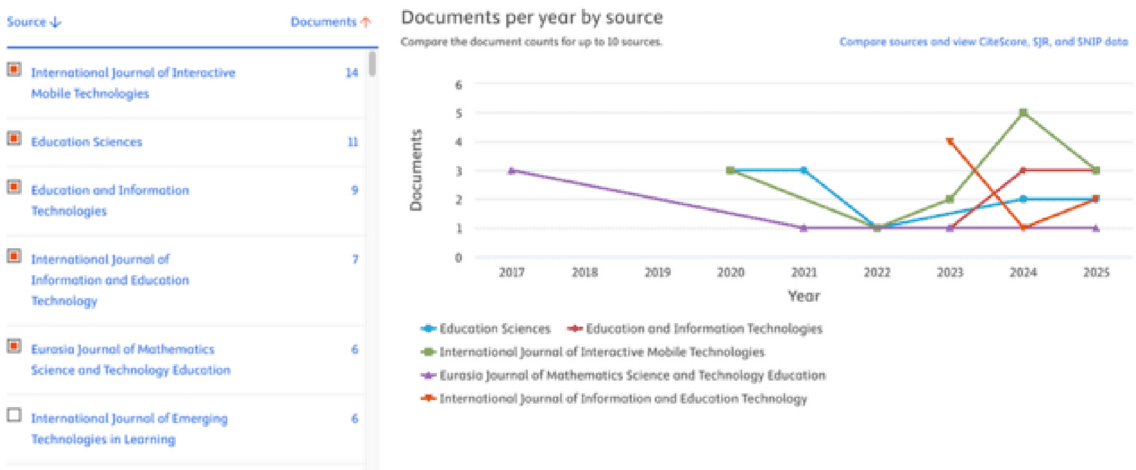

Figure 3. Documents per Year by Top Journal Sources

Table 1. Top Five Journals Publishing AR in Mathematics Education Research

Source Title	CiteScore	Percentile	% Cited	SJR	Publisher	Articles
International Journal of Interactive Mobile Technologies	2.9	76% (Q1)	68	0.394	Kassel University Press	14
Education Sciences	3.4	84% (Q1)	72	0.694	MDPI	11
Education and Information Technologies	5.2	90% (Q1)	80	1.045	Springer Nature	9
International Journal of Information and Education Technology	2.1	71% (Q2)	65	0.412	EJournal Publishing	7
Eurasia Journal of Mathematics, Science and Technology Education	2.8	78% (Q1)	70	0.512	Modestum	6

As shown in Table 1, the International Journal of Interactive Mobile Technologies (iJIM) is the most productive journal (14 articles), followed by Education Sciences (11 articles) and Education and Information Technologies (9 articles). Notably, four of the five leading journals are classified as Quartile 1, reflecting the high quality of the publication venues in this field. Education and Information Technologies (Springer Nature) has the highest CiteScore (5.2) and SJR (1.045), indicating its broad citation impact. The prominence of technology-oriented journals — rather than purely mathematics education journals — underscores the interdisciplinary nature of AR research, bridging educational technology, computer science, and mathematics pedagogy.

3.3. Contributions by Authors

A total of [N] authors from various countries contributed to the 190 articles. Figure 4 and Table 2 present the ten most productive authors in the field.

Figure 4. Distribution of Articles by Author

Table 2. Top 10 Most Productive Authors in AR–Mathematics Education Research

Author	Documents	Affiliation	Country
Lavicza, Z.	6	Johannes Kepler University Linz	Austria
Ahmad, N.I.N.	3	Universiti Kebangsaan Malaysia	Malaysia
Anwar, L.	3	Universitas Negeri Malang	Indonesia
Cai, S.	3	Beijing Normal University	China
Haas, B.	3	Johannes Kepler University Linz	Austria
Johar, R.	3	Universitas Syiah Kuala	Indonesia
Junaini, S.N.	3	Universiti Malaysia Sarawak	Malaysia
Amin, M.	2	Universitas Negeri Surabaya	Indonesia
Amir, M.F.	2	Universitas Muhammadiyah Sidoarjo	Indonesia
Angraini, L.M.	2	Universitas Islam Riau	Indonesia

Lavicza Z. from Johannes Kepler University Linz (Austria) is the most productive author with 6 publications, reflecting a sustained research programme on technology-enhanced mathematics education. Six authors — Ahmad N.I.N., Anwar L., Cai S., Haas B., Johar R., and Junaini S.N. — each contributed 3 articles. The presence of Southeast Asian researchers among the top authors is consistent with the country-level findings discussed below, confirming that Indonesian and Malaysian researchers are playing a leading role in this field. The collaboration between Lavicza Z. and Haas B. from Johannes Kepler University Linz suggests a productive research partnership, frequently situated within GeoGebra-based AR learning environments (Haas et al., 2021). GeoGebra AR has emerged as one of the most widely adopted tools for AR-based mathematics instruction, particularly for exploring three-dimensional geometry and real-world mathematical situations outside the classroom (El Bedewy et al., 2022; Caridade, 2022).

3.4. Contributions by Institutions

A total of [N] institutions from various countries contributed to the 190 articles. Table 3 presents the top ten institutions ranked by document count.

Table 3. Top 10 Most Productive Institutions in AR–Mathematics Education Research

Institution	Country	Documents
Universitas Negeri Malang	Indonesia	7
Alanya Alaaddin Keykubat University	Turkey	7
Universiti Kebangsaan Malaysia	Malaysia	6
Johannes Kepler University Linz	Austria	6
Universitas Negeri Yogyakarta	Indonesia	6

Institution	Country	Documents
Universitas Pendidikan Indonesia	Indonesia	6
Universitas Negeri Padang	Indonesia	6
Universiti Sains Malaysia	Malaysia	5
University College Dublin	Ireland	4
Beijing Normal University	China	4

Universitas Negeri Malang (Indonesia) and Alanya Alaaddin Keykubat University (Turkey) jointly lead with 7 publications each, followed by Universiti Kebangsaan Malaysia, Johannes Kepler University Linz, Universitas Negeri Yogyakarta, Universitas Pendidikan Indonesia, and Universitas Negeri Padang, all with 6 publications. The strong representation of Indonesian institutions corroborates the country-level findings and reflects sustained institutional investment in AR-integrated mathematics education research. The presence of Johannes Kepler University Linz (Austria) highlights the international dimension of the field through its GeoGebra-linked AR research programme.

3.5. Distribution by Country

Researchers from [N] countries contributed to the 190 articles. Figure 5 and Table 4 present the distribution of articles by country.

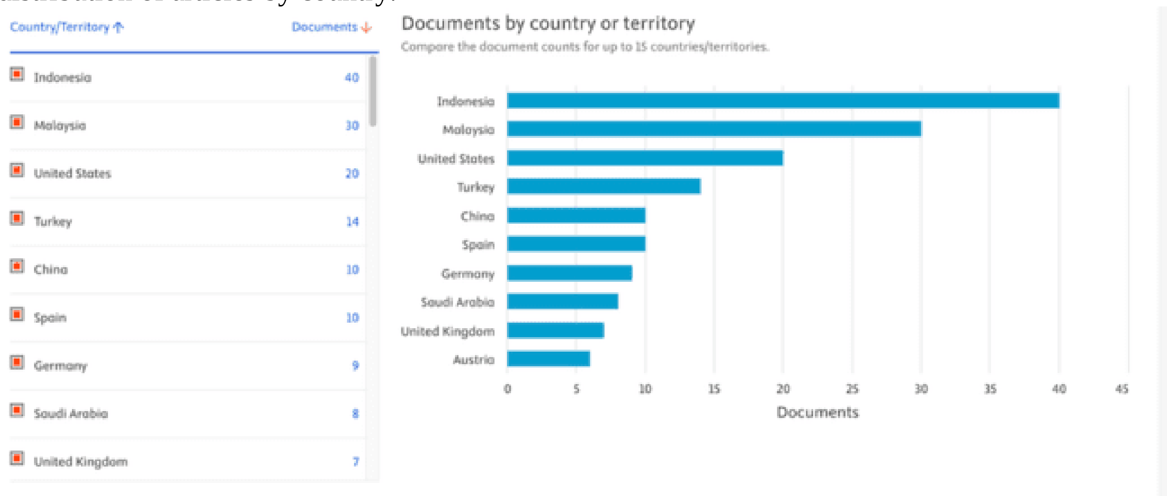

Figure 5. Documents by Country or Territory

Table 4. Top 10 Most Productive Countries in AR–Mathematics Education Research

Country	Documents	% of Total
Indonesia	40	21.1%
Malaysia	30	15.8%
United States	20	10.5%
Turkey	14	7.4%
China	10	5.3%
Spain	10	5.3%
Germany	9	4.7%
Saudi Arabia	8	4.2%
United Kingdom	7	3.7%
Austria	6	3.2%

Indonesia is the most productive country with 40 articles (21.1% of the dataset), followed by Malaysia (30 articles, 15.8%) and the United States (20 articles, 10.5%). Turkey ranks fourth (14 articles), while China and Spain each contributed 10 articles. The dominance of Indonesia and Malaysia is a notable finding that differs from patterns observed in other bibliometric studies of mathematics education, where Western countries — particularly the United States — typically lead (Gökçe & Güner, 2021; Hodiyanto et al., 2025; Suseelan et al., 2022). This reflects the rapid growth of AR-based educational research in Southeast Asia, driven by government initiatives to integrate educational technology into school curricula, the widespread adoption of smartphones, and strong inter-university collaboration networks in the region (Suranto et al., 2026). Southeast Asia has experienced an accelerated expansion of digital technology adoption, with an estimated 400 million internet users in the region and dramatic growth in online connectivity since 2020 (Antoninis et al., 2023). The high density of Indonesian and Malaysian institutions among the top contributors also reflects national investments in STEM integration and educational technology, consistent with findings from broader bibliometric analyses of STEM research output in ASEAN countries (Ha et al., 2020).

3.6. Keywords and Terms Analysis

Figure 6 presents the network visualisation of keyword co-occurrences across the 190 articles. Five major research clusters were identified, distinguished by colour.

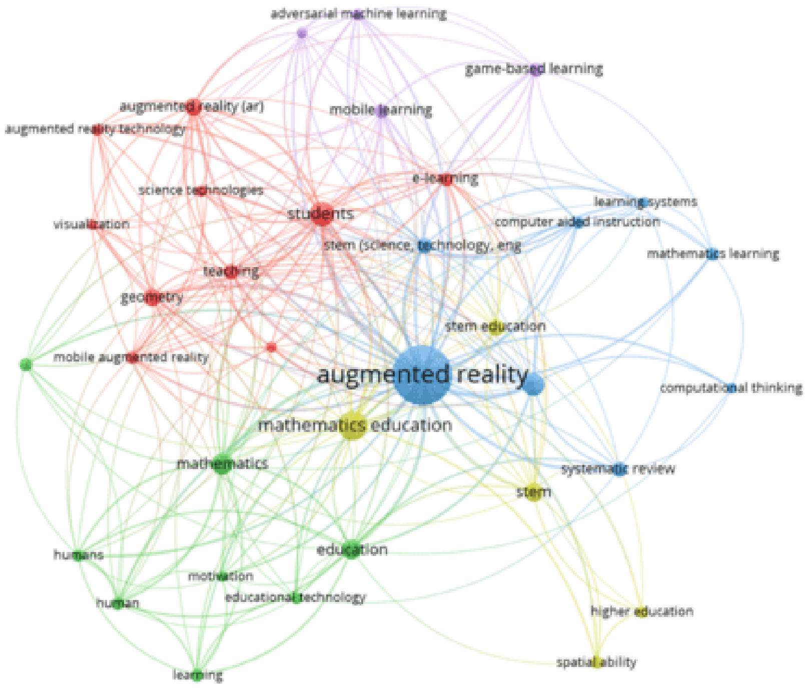

Figure 6. Network Visualisation of Author Keywords

The red cluster groups keywords related to AR technology and classroom learning, including augmented reality (AR), augmented reality technology, students, teaching, geometry, visualization, science technologies, mobile augmented reality, and e-learning — reflecting foundational studies on how AR tools are implemented in instructional settings (Ahmad & Junaini, 2020; Bulut & Borromeo Ferri, 2023). The centrality of geometry in this cluster aligns with findings from systematic reviews identifying geometry as the most extensively studied topic in AR-mathematics research, owing to the high visualisation demands of three-dimensional concepts (İslim et al., 2024; Cetintav & Yilmaz, 2023). The blue cluster centres on STEM education, encompassing stem education, STEM (science, technology, engineering), computer-aided instruction, learning systems, mathematics learning, and computational thinking, indicating a strong interdisciplinary connection between AR and STEM (Hidayat & Wardat, 2024; Tene et al., 2024). The co-occurrence of computational thinking within the STEM cluster is consistent with growing evidence that AR environments can scaffold algorithmic reasoning and abstraction skills (Lin et al., 2021; Angraini et al., 2024). The green cluster includes mathematics, humans, human, motivation, learning, educational technology, and education, highlighting studies on learner affect and broader educational contexts. The high co-occurrence of motivation within this cluster reflects the well-documented positive effect of AR on student engagement and intrinsic motivation (Chang et al., 2022; Amores-Valencia et al., 2022). The yellow-green cluster features mathematics education, STEM, higher education, spatial ability, and systematic review — suggesting growing attention to AR in higher education and its impact on spatial ability, a core cognitive skill in mathematics. The cluster aligns with evidence that AR effectively enhances spatial visualisation and mental rotation abilities, particularly in geometry contexts (Del Cerro Velázquez & Morales Méndez, 2021; Krüger et al., 2022; Flavin et al., 2025). A smaller purple cluster includes game-based learning, mobile learning, and adversarial machine learning, pointing to emerging intersections between AR, gamification, and artificial intelligence (Hussein et al., 2022; Hui & Mahmud, 2023).

Figure 7 presents the overlay visualisation, displaying the average publication year of each keyword. Keywords appearing in yellow-green (approximately 2023–2024) represent the most recently active themes: adversarial machine learning, game-based learning, computational thinking, systematic review, STEM education, and spatial ability. The recency of these themes aligns with meta-analytical and review evidence confirming that AR's intersection with STEM (Tene et al., 2024), computational thinking (Lin et al., 2021), and spatial ability (Flavin et al., 2025) are among the most dynamic frontiers in the field. Keywords in darker blue-purple (approximately 2022 or earlier) represent more established themes — augmented reality, students, teaching, and geometry — confirming that the foundational topics of the field were studied earlier and that the current frontier lies at the intersection of AR with STEM, computational thinking, and spatial skills. This temporal pattern is consistent with overlay findings from comparable bibliometric analyses of AR in education more broadly (Singh et al., 2024) and AR in STEM specifically (Hidayat & Wardat, 2024).

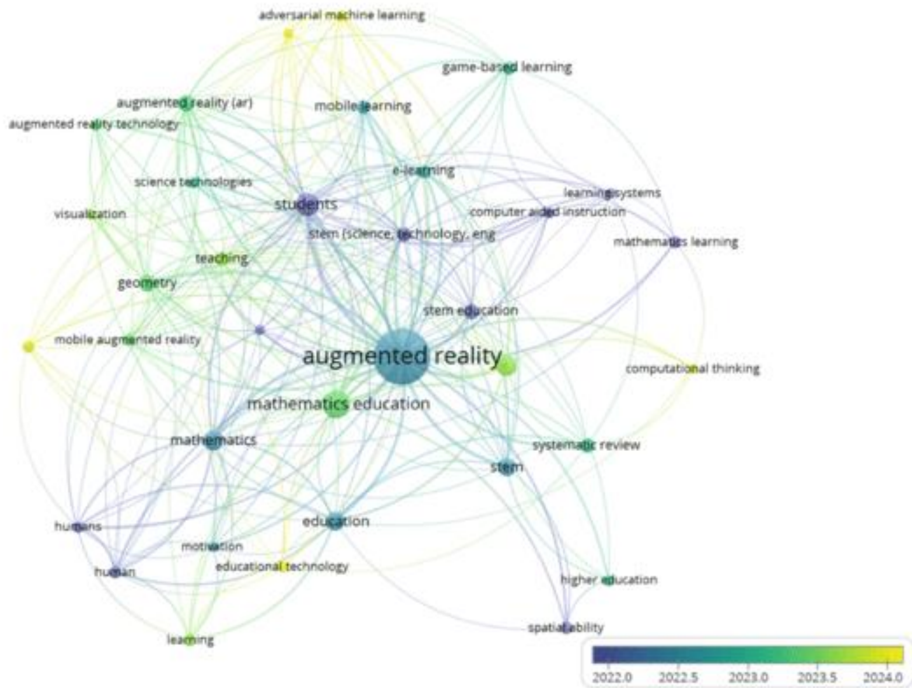

Figure 7. Overlay Visualisation of Author Keywords

Figure 8 shows the density visualisation, indicating the volume of research associated with each keyword. The brightest areas (yellow) correspond to augmented reality and STEM education, confirming these as the most heavily researched themes. The high density in the STEM cluster corroborates systematic review evidence documenting the extensive use of AR across science, technology, engineering, and mathematics disciplines (Hidayat & Wardat, 2024; Tene et al., 2024). Mathematics education and mathematics appear in green, reflecting moderate but substantial research volume. Keywords such as spatial ability, computational thinking, game-based learning, higher education, and adversarial machine learning appear in darker blue, indicating that these areas are relatively underexplored. This scarcity of density is particularly noteworthy given that spatial ability is widely recognised as a foundational cognitive skill for mathematical achievement, especially in geometry and measurement (Lowrie et al., 2019; Del Cerro Velázquez & Morales Méndez, 2021). Similarly, although AR holds strong theoretical potential for scaffolding computational thinking through interaction with abstract digital objects (Lin et al., 2021), empirical studies examining this connection within mathematics education remain limited. The lower density of game-based learning in the AR mathematics space also contrasts with the growing body of evidence demonstrating the positive effects of game-based approaches on student motivation and achievement in mathematics (Hussein et al., 2022; Hui & Mahmud, 2023; Debrenti, 2024). The low density of higher education as a keyword further highlights a gap in the literature, given that systematic reviews of AR in higher education confirm its underutilisation in mathematics and language disciplines compared to health and engineering fields (Sümer & Vaněček, 2025). This pattern reveals important opportunities for future research: studies linking AR to spatial ability development, computational thinking, and game-based approaches in mathematics education remain limited and represent high-value research directions.

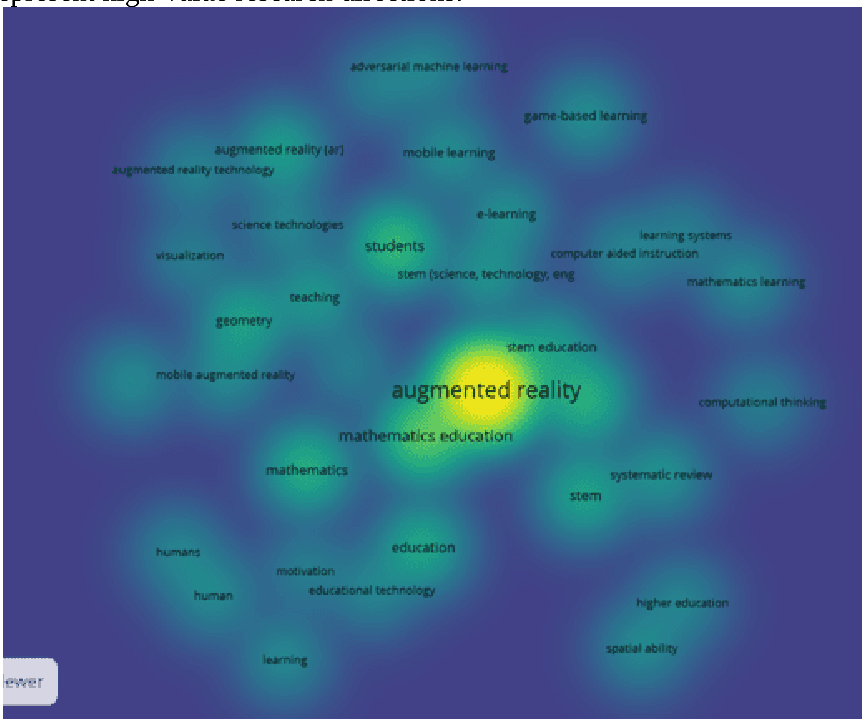

Figure 8. Density Visualisation of Author Keywords

4. Conclusion

This bibliometric study analysed 190 open-access Scopus-indexed journal articles on augmented reality in mathematics education published between 2016 and 2025. The key findings are as follows. First, AR research in mathematics education has grown substantially, with 2024 and 2025 each recording the highest annual output (46 articles), demonstrating that this is an active and expanding field. Second, the International Journal of Interactive Mobile Technologies is the most productive journal source, and the leading venues are predominantly Q1 journals, reflecting high research quality. Third, Lavicza Z. from Johannes Kepler University Linz is the most productive author (6 articles), and Southeast Asian researchers from Indonesia and Malaysia are among the most active contributors globally. Fourth, Indonesia is the most productive country (40 articles, 21.1%), a distinctive finding that differentiates AR–mathematics education research from other subfields where Western countries typically dominate. Fifth, keyword co-occurrence analysis identified five major clusters — AR technology and student learning, STEM education, mathematics and educational technology, geometry and teaching, and mobile AR — while emerging themes include computational thinking, spatial ability, game-based learning, higher education contexts, and AI intersections with AR.

Future research should address these underexplored areas. Studies examining the effect of AR on spatial ability and computational thinking in mathematics are scarce but theoretically well-grounded. Research at the higher education level and longitudinal studies assessing the sustained impact of AR on mathematics achievement are also needed. This study is limited to the Scopus database and open-access articles; future bibliometric analyses could combine the Web of Science database and non-open-access publications for a more comprehensive landscape. Incorporating systematic content analysis alongside the quantitative bibliometric approach would further enrich interpretations of the field's development.

References

Adedoyin, O.B., & Soykan, E. (2023). Covid-19 pandemic and online learning: The challenges and opportunities. Interactive Learning Environments, 31(2), 863–875. https://doi.org/10.1080/0309877X.2022.2079970

Ahmad, N.I.N., & Junaini, S.N. (2020). Augmented reality for learning mathematics: A systematic literature review. International Journal of Emerging Technologies in Learning, 15(16), 106–122. https://doi.org/10.3991/ijet.v15i16.14961

Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. Educational Research Review, 20, 1–11. https://doi.org/10.1016/j.edurev.2016.11.002

Amores-Valencia, A., Burgos, D., & Branch-Bedoya, J.W. (2022). Influence of motivation and academic performance in the use of augmented reality in education: A systematic review. Frontiers in Psychology, 13, Article 1011409. https://doi.org/10.3389/fpsyg.2022.1011409

Angraini, L.M., Yolanda, F., & Muhammad, I. (2024). Augmented reality: The influence on students' computational thinking skills in mathematics. International Journal of Instruction, 17(1), 521–538. https://doi.org/10.29333/iji.2024.17130a

Antoninis, M., Alcott, B., Al Hadheri, S., April, D., Fouad Barakat, B., Barrios Rivera, M., Baskakova, Y., Barry, M., Bekkouche, Y., & Caro Vasquez, D. (2023). Global Education Monitoring Report 2023: Technology in education: A tool on whose terms?

Börner, K., Chen, C., & Boyack, K.W. (2003). Visualizing knowledge domains. Annual Review of Information Science and Technology, 37(1), 179–255. https://doi.org/10.1002/aris.1440370106

Bujak, K.R., Radu, I., Catrambone, R., MacIntyre, B., Zheng, R., & Golubski, G. (2013). A psychological perspective on augmented reality in the mathematics classroom. Computers & Education, 68, 536–544. https://doi.org/10.1016/j.compedu.2013.02.017

Bulut, M., & Borromeo Ferri, R. (2023). A systematic literature review on augmented reality in mathematics education. European Journal of Science and Mathematics Education, 11(3), 556–572. https://doi.org/10.30935/scimath/13124

Cai, S., Liu, E., Shen, Y., Liu, C., Li, S., & Shen, Y. (2021). Probability learning in mathematics using augmented reality: Impact on student's learning gains and attitudes. Interactive Learning Environments, 29(3), 382–395. https://doi.org/10.1080/10494820.2019.1696839

Caridade, C.M.R. (2022). GeoGebra augmented reality: Ideas for teaching and learning math. In F. Yilmaz et al. (Eds.), Mathematical Methods for Engineering Applications (Springer Proceedings in Mathematics & Statistics, vol. 384, pp. 251–261). Springer. https://doi.org/10.1007/978-3-030-96401-6_22

Cetintav, G., & Yilmaz, R. (2023). The effect of augmented reality technology on middle school students' mathematic academic achievement, self-regulated learning skills, and motivation. Journal of Educational Computing Research, 61(7), 1483–1504. https://doi.org/10.1177/07356331231176022

Chang, H.Y., Binali, T., Liang, J.C., Chiou, G.L., Cheng, K.H., Lee, S.W.Y., & Tsai, C.C. (2022). Ten years of augmented reality in education: A meta-analysis of (quasi-)experimental studies to investigate the impact. Computers & Education, 191, 104641. https://doi.org/10.1016/j.compedu.2022.104641

Debrenti, E. (2024). Game-Based Learning experiences in primary mathematics education. Frontiers in Education, 9, 1331312. https://doi.org/10.3389/feduc.2024.1331312

Del Cerro Velázquez, F., & Morales Méndez, G. (2021). Systematic review of the development of spatial intelligence through augmented reality in STEM knowledge areas. Mathematics, 9(23), 3067. https://doi.org/10.3390/math9233067

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W.M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. Journal of Business Research, 133, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

El Bedewy, S., Lavicza, Z., Haas, B., & Lieban, D. (2022). A STEAM practice approach to integrate architecture, culture and history to facilitate mathematical problem-solving. Education Sciences, 12(1), 9. https://doi.org/10.3390/educsci12010009

Ellegaard, O., & Wallin, J.A. (2015). The bibliometric analysis of scholarly production: How great is the impact? Scientometrics, 105(3), 1809–1831. https://doi.org/10.1007/s11192-015-1645-z

Flavin, E., Hwang, S., & Flavin, M. T. (2025). Augmented reality for mathematics achievement: A meta-analysis of main and moderator effects. International Journal of Science and Mathematics Education, 1–26.

Gökçe, S., & Güner, P. (2021). Forty years of mathematics education: 1980–2019. International Journal of Education in Mathematics, Science and Technology, 9(3), 514–539. https://doi.org/10.46328/IJEMST.1361

Ha, C.T., Thao, T.T.P., Trung, N.T., Huong, L.T.T., Dinh, N.V., & Trung, T. (2020). A bibliometric review of research on STEM education in ASEAN: Science mapping the literature in Scopus database, 2000 to 2019. Eurasia Journal of Mathematics, Science and Technology Education, 16(10), em1889. https://doi.org/10.29333/ejmste/8500

Haas, B., Kreis, Y., & Lavicza, Z. (2021). Integrated STEAM approach in outdoor trails with elementary school pre-service teachers. Educational Technology & Society, 24(4), 205–219.

Hallinger, P., & Kovačević, J. (2019). A bibliometric review of research on educational administration: Science mapping the literature, 1960 to 2018. Review of Educational Research, 89(3), 335–369. https://doi.org/10.3102/0034654319830380

Hidayat, R., & Wardat, Y. (2024). A systematic review of augmented reality in Science, Technology, Engineering and Mathematics education. Education and Information Technologies, 29(8), 9257–9282. https://doi.org/10.1007/s10639-023-12157-x

Hodiyanto, H., Budiarto, M.T., Ekawati, R., Susanti, G., Kim, J., & Bongtiwon, D.M.R. (2025). Trends of abstraction research in mathematics education: A bibliometric analysis. Infinity Journal, 14(1), 125–142. https://doi.org/10.22460/infinity.v14i1.p125-142

Hui, H.B., & Mahmud, M.S. (2023). Influence of game-based learning in mathematics education on the students' cognitive and affective domain: A systematic review. Frontiers in Psychology, 14, Article 1105806. https://doi.org/10.3389/fpsyg.2023.1105806

Hussein, M.H., Ow, S.H., Elaish, M.M., & Jensen, E.O. (2022). Digital game-based learning in K-12 mathematics education: A systematic literature review. Education and Information Technologies, 27(2), 2859–2891. https://doi.org/10.1007/s10639-021-10694-7

İslim, Ö.F., Namli, Ş., Sevim Çirak, N., Özçakir, B., & Lavicza, Z. (2024). Augmented reality in mathematics education: A systematic review. Participatory Educational Research, 11(4), 115–139.

Kadarisma, G., Juandi, D., & Darhim, D. (2024). Global trends in flipped classroom research within mathematics education over the past two decades: A bibliometric analysis. Infinity Journal, 13(2), 531–552. https://doi.org/10.22460/infinity.v13i2.p531-552

Kaufmann, H., & Schmalstieg, D. (2003). Mathematics and geometry education with collaborative augmented reality. Computers & Graphics, 27(3), 339–345. https://doi.org/10.1016/S0097-8493(03)00028-1

Koumpouros, Y. (2024). Revealing the true potential and prospects of augmented reality in education. Smart Learning Environments, 11(1), 2. https://doi.org/10.1186/s40561-023-00288-0

Krüger, J.M., Palzer, K., & Bodemer, D. (2022). Learning with augmented reality: Impact of dimensionality and spatial abilities. Computers and Education Open, 3, 100065.

Lin, Y.S., Chen, S.Y., Tsai, C.W., & Lai, Y.H. (2021). Exploring computational thinking skills training through augmented reality and AIoT learning. Frontiers in Psychology, 12, Article 640115. https://doi.org/10.3389/fpsyg.2021.640115

Lowrie, T., Logan, T., & Hegarty, M. (2019). The influence of spatial visualization training on students' spatial reasoning and mathematics performance. Journal of Cognition and Development, 20(5), 729–751. https://doi.org/10.1080/15248372.2019.1653298

Nincarean, D., Alia, M.B., Halim, N.D.A., & Rahman, M.H.A. (2013). Mobile augmented reality: The potential for education. Procedia — Social and Behavioral Sciences, 103, 657–664. https://doi.org/10.1016/j.sbspro.2013.10.385

Phan, T.T., Do, T.T., Trinh, T.H., Tran, T., Duong, H.T., Trinh, T.P.T., Do, B.C., & Nguyen, T.-T. (2022). A bibliometric review on realistic mathematics education in Scopus database between 1972–2019. European Journal of Educational Research, 11(2), 1133–1149. https://doi.org/10.12973/eu-jer.11.2.1133

Singh, S., Kaur, A., & Gulzar, Y. (2024). The impact of augmented reality on education: A bibliometric exploration. Frontiers in Education, 9, 1458695. https://doi.org/10.3389/feduc.2024.1458695

Suranto, B., Kovač, N., Haryono, K., Abdul Rahman, S. F., Mohd Shukri, A. F., Suder, M., Kusa, R., & Žugić, D. (2026). State of digitalization in the Southeast Asia region–bibliometric analysis. Quality & Quantity, 60(1), 1053–1080.

Suseelan, M., Chew, C.M., & Chin, H. (2022). Research on mathematics problem solving in elementary education conducted from 1969 to 2021: A bibliometric review. International Journal of Education in Mathematics, Science and Technology, 10(4), 1003–1029. https://doi.org/10.46328/ijemst.2198

Tene, T., Marcatoma Tixi, J. A., Palacios Robalino, M. D. L., Mendoza Salazar, M. J., Vacacela Gomez, C., & Bellucci, S. (2024). Integrating immersive technologies with STEM education: A systematic review. Frontiers in Education, 9, 1410163. https://doi.org/10.3389/feduc.2024.1410163

Sümer, M., & Vaněček, D. (2025). A systematic review of virtual and augmented realities in higher education: Trends and issues. Innovations in Education and Teaching International, 62(3), 811–822. https://doi.org/10.1080/14703297.2024.2382854

Van Eck, N.J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 84(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

Yuen, S.C.Y., Yaoyuneyong, G., & Johnson, E. (2011). Augmented reality: An overview and five directions for AR in education. Journal of Educational Technology Development and Exchange, 4(1), 119–140. https://doi.org/10.18785/jetde.0401.10

Zupic, I., & Čater, T. (2015). Bibliometric methods in management and organization. Organizational Research Methods, 18(3), 429–472. https://doi.org/10.1177/1094428114562629