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STEM Approaches in Primary Education: A Bibliometric Analysis of Global Research Trends

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Abstract
STEM approaches have become a prominent strategy for building foundational scientific, technological, and mathematical competencies in primary education, yet the structure of the research field remains insufficiently mapped. This study analyzed global publication and citation trends, leading contributors, collaboration patterns, and thematic evolution in research on STEM approaches in primary education. A bibliometric design combining performance analysis and science mapping was applied to 55 journal articles published between 2017 and 2026 and analyzed with bibliometrix and Biblioshiny. The results show an annual growth rate of 31.8%, with 89.1% of the articles published since 2021, and an average of 9.04 citations per document, with citation impact peaking for the 2021 cohort. Production is widely dispersed: 43 of 48 sources published a single article, no author contributed more than two documents, and Türkiye, China, the United States, and Malaysia led corresponding-author output. Only 16.36% of documents involved international co-authorship. Thematic analysis identified STEM education, primary education, and primary schools as basic themes; educational robotics, engineering, mathematics, and computational thinking as motor themes; and inquiry-based and project-based learning as developed but isolated niche themes. Educational robotics dominated early work, whereas STEM learning attitudes, educational technology, and environmental awareness emerged most recently. The findings reveal a rapidly growing but fragmented field and point to opportunities for stronger international collaboration, closer integration of pedagogy and technology, and links with sustainability education.

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INTRODUCTION

Science, technology, engineering, and mathematics (STEM) education has become a global educational priority because societies increasingly depend on citizens who can reason scientifically, work with technology, and solve complex problems (Bybee, 2010; English, 2016). Rather than treating the four disciplines as separate subjects, contemporary STEM approaches emphasize integration, in which students apply knowledge from several disciplines to authentic problems (Kelley & Knowles, 2016). At the primary level, this orientation is particularly consequential, because the conceptual foundations, dispositions, and attitudes that learners develop in the early years shape their later participation in science and technology pathways. Primary education is also where STEM implementation meets persistent challenges, including the limited disciplinary preparation of generalist teachers and uncertainty about what integration means in classroom practice (Margot & Kettler, 2019). These concerns are relevant to education

for sustainability and transformation, since scientific literacy and problem-solving (Salim et al., 2024) are widely regarded as prerequisites for engaging with environmental and societal challenges.

Research on STEM approaches in primary education has diversified alongside developments in educational technology and pedagogy. Studies have examined educational robotics as a context for learning science, mathematics, and engineering concepts (Benitti, 2012; Bers et al., 2014), computational thinking as a core competence of the digital age (Wing, 2006), and augmented reality as a means of enhancing learning experiences (Akçayır & Akçayır, 2017; Wibowo et al., 2026), alongside inquiry-based and problem-based pedagogies (Salim et al., 2024) and mathematical thinking among primary school students (Herzamzam et al., 2024). Existing syntheses, however, tend either to address STEM education across all levels of schooling, as in the systematic review of STEM research trends by Li et al. (2020), or to concentrate on a single dimension, such as teachers' perceptions of integration (Margot & Kettler, 2019).

Bibliometric analysis offers a systematic and reproducible way to map such a dispersed literature. By quantifying publication output, citation impact, authorship, and keyword structures, it reveals not only how much research exists but also how knowledge is organized, who produces it, and where it is heading (Donthu et al., 2021; Zupic & Čater, 2015). Despite the rapid expansion of primary-level STEM research, a focused bibliometric portrait of this field remains limited. It is not yet clear how publication and citation trends have evolved, which authors, institutions, and countries drive the field, how researchers collaborate across borders, and which themes are established or emerging. Without this evidence, researchers risk duplicating efforts, and educators and policymakers lack a map of where the evidence base is strong or thin.

This study therefore presents a bibliometric analysis of global research on STEM approaches in primary education. It addresses three research questions: (1) How have publication and citation trends in research on STEM approaches in primary education evolved over time? (2) Which authors, journals, institutions, and countries are the most productive and influential in this field, and what are the patterns of collaboration among researchers and across countries? (3) What are the dominant and emerging themes in research on STEM approaches in primary education, and how have these themes evolved over time?

METHOD

This study employed a bibliometric design that combines performance analysis, which evaluates the contributions of research constituents such as authors, sources, institutions, and countries, with science mapping, which examines the intellectual and conceptual structure of a field (Donthu et al., 2021; Zupic & Čater, 2015). The unit of analysis was the published document, and no human participants were involved.

Bibliographic records were retrieved from Scopus, a curated multidisciplinary database with broad coverage of education journals (Baas et al., 2020; Mongeon & Paul-Hus, 2016), on 18 October 2026. The search string (("STEM education" OR "STEM learning" OR "STEM teaching" OR "integrated STEM" OR "STEM integration" OR "STEM approach*" OR "STEM-based learning") AND ("elementary school*" OR "primary school*" OR "elementary education" OR "primary education")) was applied. The selection followed the PRISMA stages of identification, screening, eligibility, and inclusion (Figure 1). Of the 113 records identified, 5 published outside the 2016–2026 period were removed, leaving 108 records for screening. Non-journal documents (reviews, conference papers, data papers, editorials, and short surveys) were then excluded, leaving 58 articles for the eligibility assessment, and 3 non-English articles were excluded. These steps produced a final dataset of 55 documents published in 48 sources between 2017 and 2026. Because data were collected during 2026, the count for that year is partial.

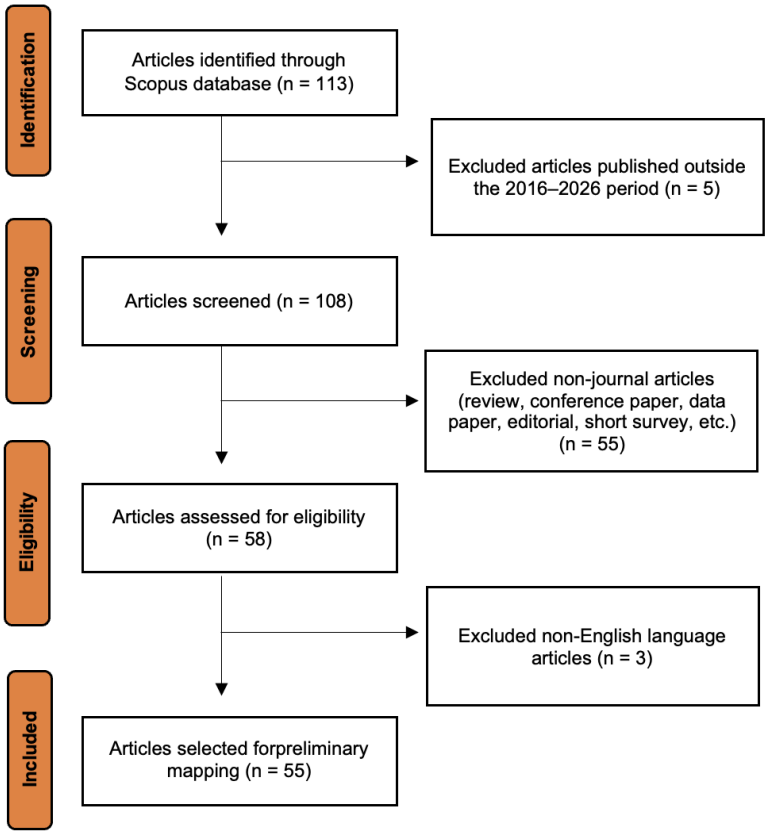


Figure 1. PRISMA flow diagram of the bibliometric data selection process

The dataset was analyzed with the bibliometrix R package and its web interface Biblioshiny (Aria & Cuccurullo, 2017). The analysis proceeded in three blocks aligned with the research questions. For the first research question, the main information of the dataset, annual scientific production, annual growth rate, and average citations per article per year were computed. For the second, the most relevant sources, authors, affiliations, and corresponding authors' countries were identified through document counts, with country output divided into single-country publications (SCP) and multiple-country publications (MCP) to capture international collaboration. Citation influence was assessed through the most globally cited documents, using total citations (TC), total citations per year (TCY), and normalized total citations (NTC), the last of which divides a document's citations by the average for documents published in the same year. Collaboration was further described by the number of co-authors per document, the share of single-authored documents, and the percentage of internationally co-authored documents.

For the third research question, keywords were analyzed through a word cloud of the most frequent terms; a trend topics analysis that places each term at the median year of its occurrence, with an interquartile range; a thematic map that positions keyword clusters by centrality (relevance degree) and density (development degree) into motor, basic, niche, and emerging or declining themes (Callon et al., 1991; Cobo et al., 2011); and a conceptual structure map based on multiple correspondence analysis (MCA). Results were interpreted descriptively. Citation-based indicators are time dependent, so cohorts with a short citation window were interpreted with caution, and values read from the figures, such as annual average citations, are approximate.

RESULTS AND DISCUSSION

Results

Publication and citation trends

The dataset comprised 55 journal articles from 48 sources, written by 193 authors and citing 7,760 references (Table 1). The documents were published between 2017 and 2026, with an average document age of 2.69 years, which confirms that the field is young. The articles received an average of 9.036 citations each, and the annual growth rate of scientific production was 31.8%.

Table 1. Main information of the dataset

Description	Results
Timespan	2017:2026
Sources (journals, books, etc.)	48
Documents	55
Annual growth rate (%)	31.8
Document average age	2.69
Average citations per document	9.036
References	7,760
Keywords Plus (ID)	53
Author's keywords (DE)	189
Authors	193
Authors of single-authored documents	5
Single-authored documents	5
Co-authors per document	3.65
International co-authorships (%)	16.36
Document type: article	55

Scientific production grew unevenly but steadily (Figure 2). Between 2017 and 2020 the field produced only one or two articles per year, six in total (10.9% of the dataset). Output rose to six articles in both 2021 and 2022, seven in 2023, and 11 in 2024, then fell to seven in 2025 before reaching the highest annual count, 12 articles, in 2026, a year that was still in progress at the time of data collection. Overall, 49 of the 55 articles (89.1%) appeared from 2021 onward, and 30 (54.5%) from 2024 onward.

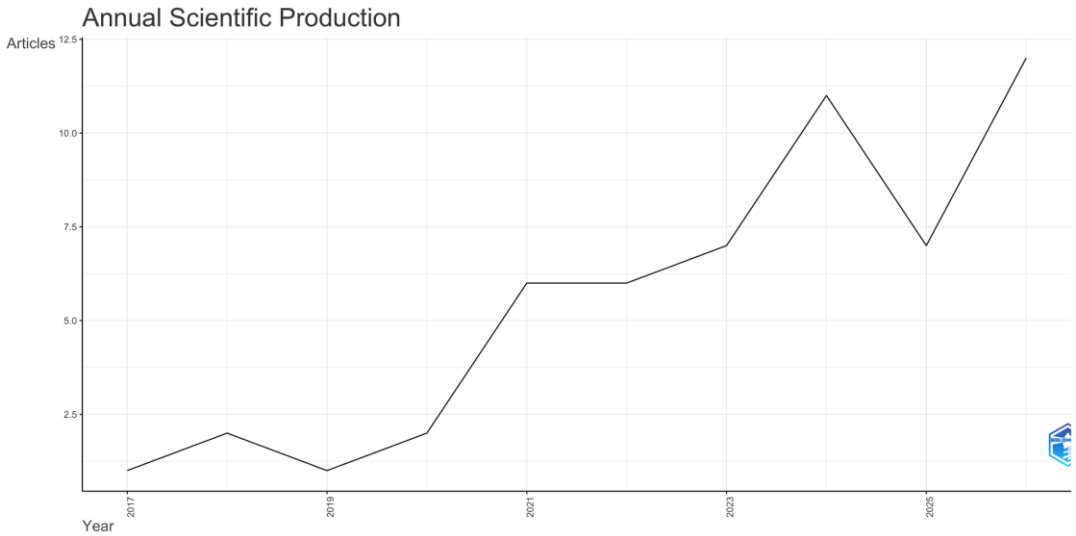


Figure 2. Annual scientific production

Citation impact followed a different trajectory (Figure 3). The average number of citations per article per year remained below 0.7 for the 2017–2019 cohorts (approximately 0.3 to 0.6), increased to about 1.6 for 2020, and peaked at about 4.8 for articles published in 2021. It then declined to about 2.1 for 2022, recovered to about 3.4 for 2023 and 3.2 for 2024, and fell to about 1.5 for 2025 and 0.25 for 2026.

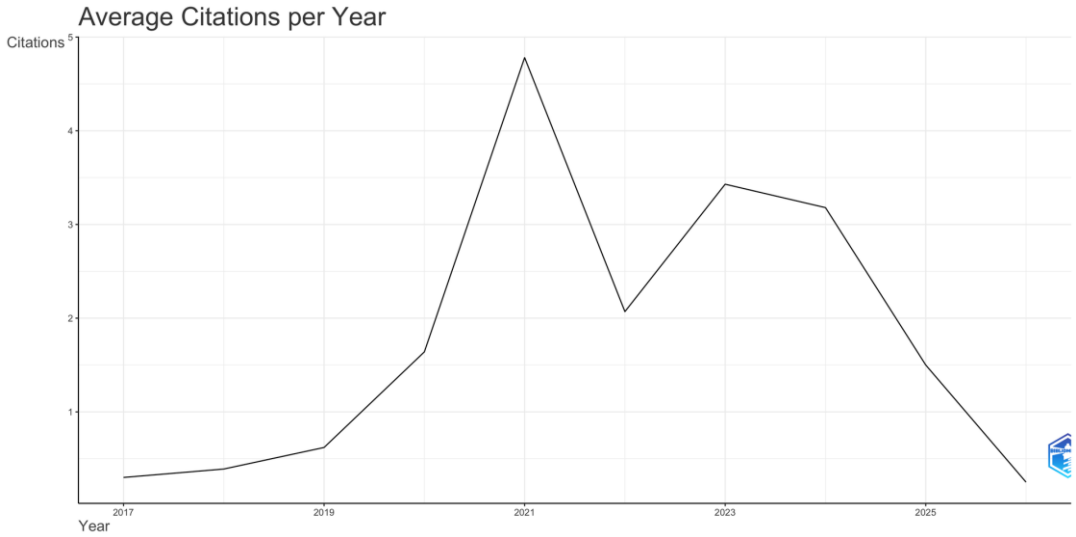


Figure 3. Average citations per year

Leading contributors, citation influence, and collaboration patterns

Publication outlets were highly dispersed (Figure 4). Frontiers in Education and Jurnal Pendidikan IPA Indonesia were the most productive sources with three articles each, followed by Education and Information Technologies, Education Sciences, and Sustainability (Switzerland) with two articles each. Every other source, including Advances in Intelligent Systems and Computing, ASM Science Journal, Australian Journal of Teacher Education, Behaviour and Information Technology, and Discover Education, contributed a single article. Because the 48 sources published 55 articles, 43 sources (89.6%) published only one article, and the five leading sources together accounted for 12 articles (21.8%).

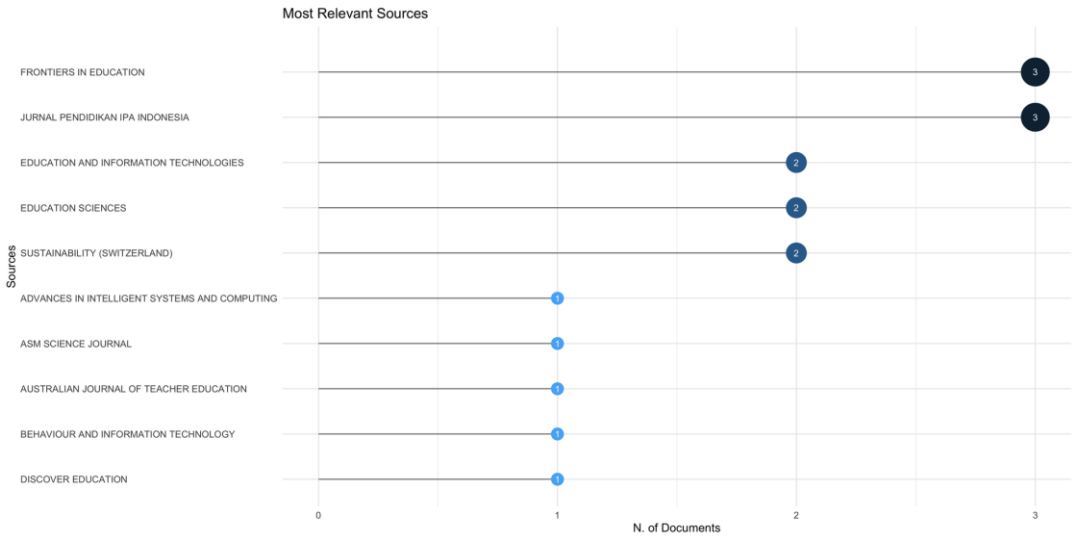


Figure 4. Most relevant sources

Author productivity was similarly flat (Figure 5). The most productive authors, Hu L, Kalzhanova A, Maat SM, Sun D, Wang X, Yang Y, Yesnazar A, and Zhorabekova A, each contributed two articles, whereas the remaining 185 of the 193 authors, for example Abdullah

NHI and Abilkhairova Z, contributed one article each. No author published more than two articles, and no group of highly prolific researchers was evident.

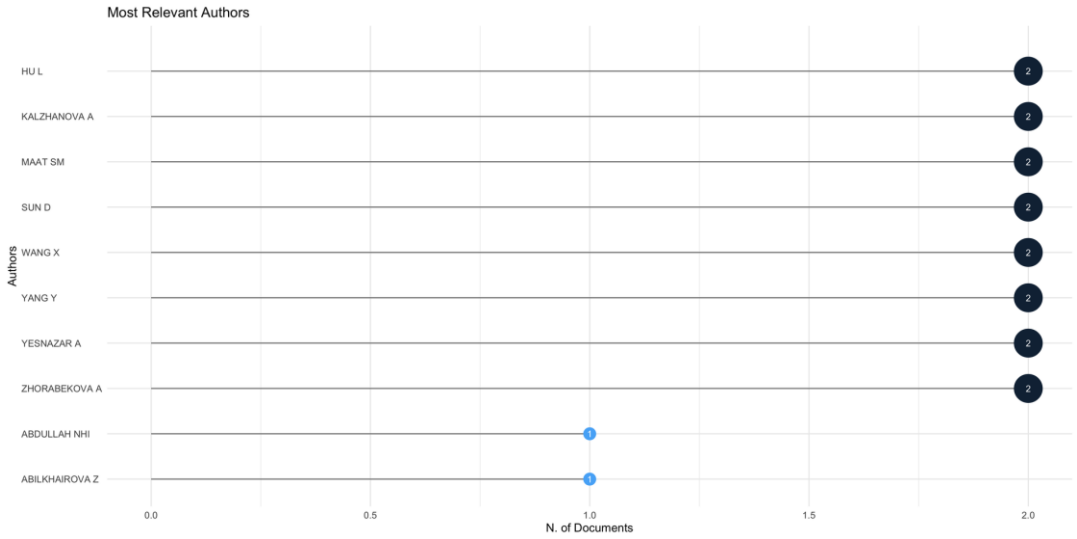


Figure 5. Most relevant authors

At the institutional level (Figure 6), Central China Normal University and Universiti Kebangsaan Malaysia led with four articles each, followed by M. Auezov South Kazakhstan University, Necmettin Erbakan University, and Universidad de Burgos with three articles each. Five further institutions, George Mason University, Istanbul Sabahattin Zaim University, Mahasarakham University, Maryville University, and Mugla Sitki Kocman University, were each affiliated with two articles. The leading institutions are located in China, Malaysia, Kazakhstan, Türkiye, Spain, the United States, and Thailand, and none accounted for more than four articles (7.3% of the dataset).

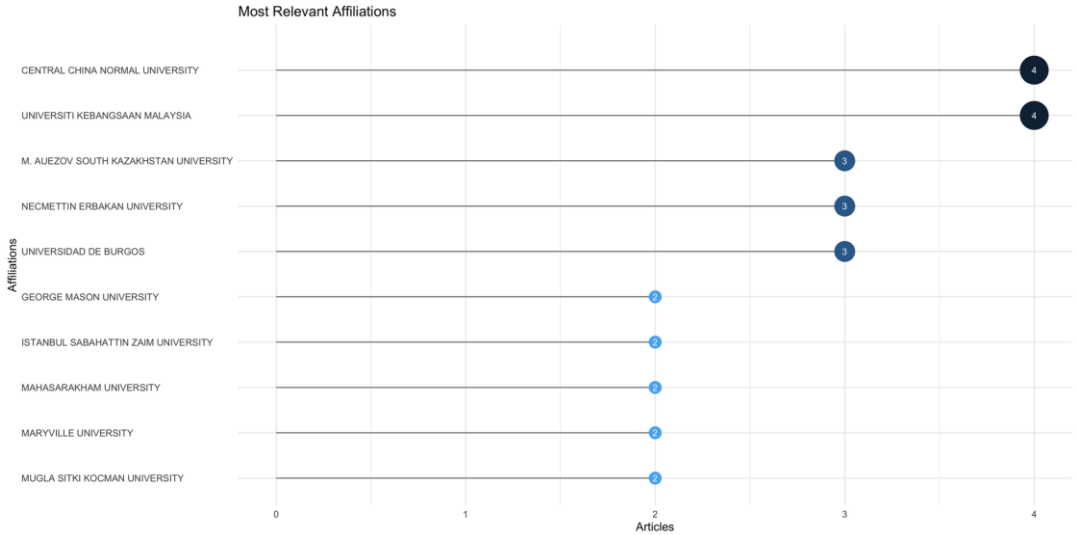


Figure 6. Most relevant affiliations

Corresponding authors' countries (Figure 7) show that Türkiye was the most productive country with eight articles (14.5%), followed by China and the United States with six articles each, Malaysia with five, Spain and Thailand with three each, and Indonesia, Ireland, and Kazakhstan with two each. Australia, Bangladesh, Cyprus, Georgia, Greece, and Hong Kong each had one article, and the other 12 articles had corresponding authors in countries not shown in the figure. The four leading countries together accounted for 25 of the 55 articles (45.5%).



Figure 7. Corresponding author's countries (SCP: single-country publications; MCP: multiple-country publications)

Collaboration was common at the author level but limited across borders. Articles had an average of 3.65 co-authors, and only five articles (9.1%) were single-authored. International co-authorship, however, characterized only 16.36% of the articles, corresponding to nine multiple-country publications. Among the countries in Figure 7, the share of multiple-country publications was highest in Indonesia (two of two articles) and Hong Kong (one of one), followed by Ireland (one of two), Türkiye (two of eight), Malaysia (one of five), and China (one of six). The United States, Spain, Thailand, and Kazakhstan, by contrast, had no internationally co-authored articles among those led by their corresponding authors.

Citation influence was concentrated in a few articles (Table 2). The most cited article, published in the Journal of Computer Assisted Learning in 2021, received 98 citations (16.33 per year), followed by articles in the International Journal of Science and Mathematics Education (42 citations), Irish Educational Studies (31), and Behaviour and Information Technology (30). The ten most cited articles together received 312 citations, about 63% of the roughly 497 citations implied by the dataset's average of 9.036 citations per article. The four articles with the highest TC (the first four entries in Table 2) also had NTC values of 3.00 or higher, meaning that each was cited at least three times as often as the average article published in the same year.

Table 2. Most globally cited documents

No	Paper	DOI	TC	TCY	NTC
1	SUN L, 2021, J COMPUT ASSISTED LEARN	10.1111/jcal.12493	98	16.33	3.42
2	LARKIN K, 2023, INT J SCI MATH EDUC	10.1007/s10763-023-10362-1	42	10.50	3.06
3	HOURIGAN M, 2022, IR EDUC STUD	10.1080/03323315.2021.1899027	31	6.20	3.00
4	HU C-C, 2024, BEHAV INF TECHNOL	10.1080/0144929X.2023.2222308	30	10.00	3.14
5	GARCÍA-CARRILLO C, 2021, EDUC SCI	10.3390/educsci11020064	23	3.83	0.80
6	KÜÇÜKAYDIN MA, 2024, EDUC INF TECHNOL	10.1007/s10639-024-12492-7	19	6.33	1.99
7	LIU X, 2023, J INTELL	10.3390/jintelligence11020036	18	4.50	1.31
8	UŞTU H, 2022, SYST PRACT ACTION RES	10.1007/s11213-021-09570-z	17	3.40	1.65
9	WEI WK, 2020, TEM J	10.18421/TEM93-53	17	2.43	1.48
10	BOZ T, 2023, INT ELECTRON J ELEM EDUC	10.26822/iejee.2023.306	17	4.25	1.24

Note. TC = total citations; TCY = total citations per year; NTC = normalized total citations.

Dominant and emerging themes, conceptual structure, and temporal trends

The word cloud (Figure 8) shows that the vocabulary of the field is anchored by the terms STEM education, STEM, education, primary education, and primary schools. Around this core, the most prominent specific terms are mathematics, computational thinking, integrated STEM, educational robots and educational robotics, augmented reality, inquiry-based learning, project-based learning, STEM learning attitude, and environmental awareness. Terms related to teachers (primary school teachers, teacher development), measurement (scale validation, confirmatory factor analysis), and research design (quasi-experimental study, case study, action research) also appear, whereas artificial intelligence, chatbots, and automation appear only marginally.

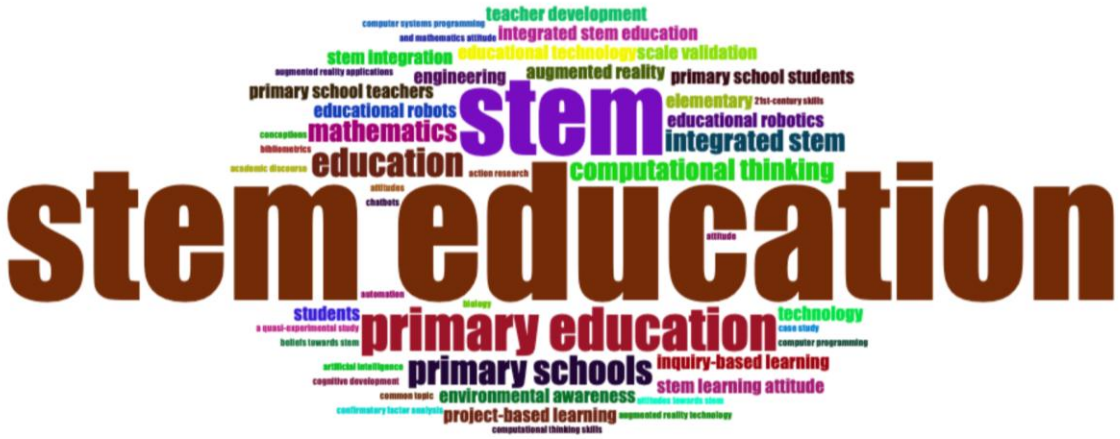


Figure 8. Word cloud

The trend topics analysis (Figure 9) reveals a clear temporal sequence. Educational robotics was the earliest prominent topic, centered on 2019, followed by mathematics in 2020 and primary school students in 2021. Engineering and teacher development appeared around 2022, and integrated STEM education, primary schools, and primary education were centered on 2023 to 2024. The general terms STEM and STEM education reached their highest frequencies around 2024, with STEM education spanning the longest period, from about 2021 to 2026. The most recent topics were STEM learning attitude and elementary, centered on 2025, and environmental awareness, educational technology, and education, centered on 2026.

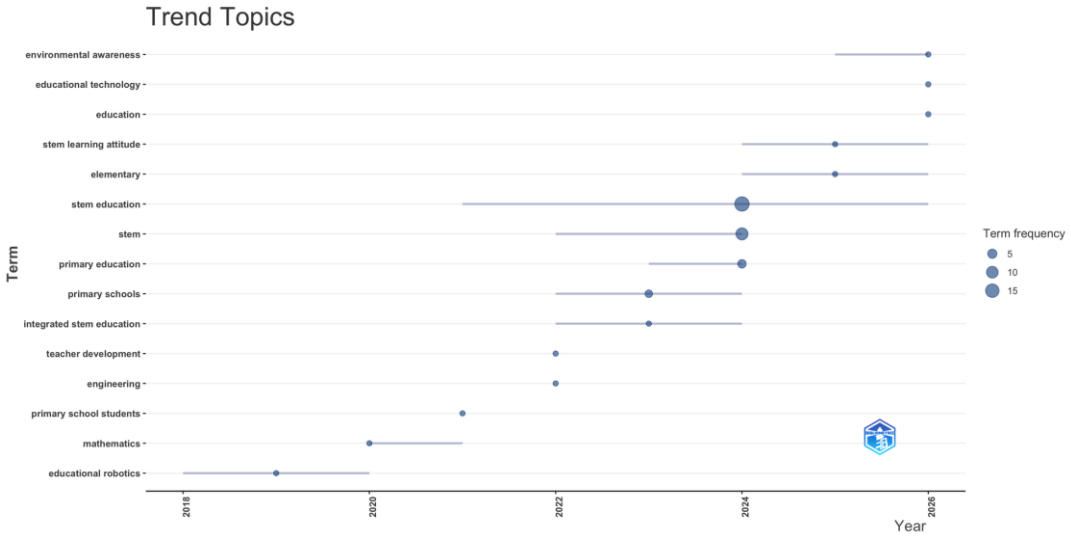


Figure 9. Trend topics

The thematic map (Figure 10; summarized in Table 3) shows how keyword clusters are structured. Two clusters occupy the motor-theme quadrant, which combines high centrality and high density: one comprising educational robotics, engineering, and mathematics, and another comprising computational thinking, primary school students, and STEM learning attitude. The largest clusters, STEM education with primary education and augmented reality, and STEM with primary schools, fall in the basic-theme quadrant, indicating high centrality but lower density. Three clusters are positioned as niche themes, with high density but low centrality: inquiry-based learning with project-based learning, primary school teachers with STEM integration, and integrated STEM with elementary. Finally, scale validation, technology, integrated STEM education, and environmental awareness fall in the emerging or declining quadrant.

Table 3. Thematic clusters by quadrant of the thematic map

Quadrant	Keyword clusters	Position
Motor themes	Educational robotics, engineering, mathematics	High centrality and density
Motor themes	Computational thinking, primary school students, STEM learning attitude	High centrality and density
Basic themes	STEM education, primary education, augmented reality	High centrality, lower density
Basic themes	STEM, primary schools	High centrality, lower density
Niche themes	Inquiry-based learning, project-based learning	High density, low centrality
Niche themes	Primary school teachers, STEM integration	High density, low centrality
Niche themes	Integrated STEM, elementary	High density, low centrality
Emerging or declining themes	Scale validation; technology; integrated STEM education; environmental awareness	Low centrality and density

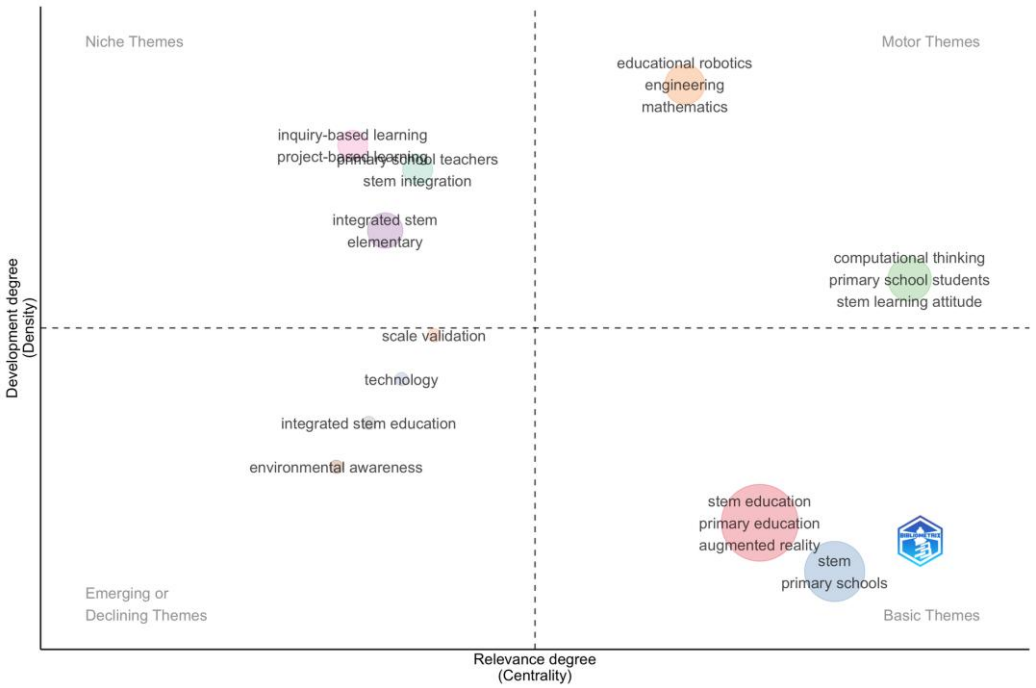


Figure 10. Thematic map

The conceptual structure map (Figure 11) explains 37.89% of the variance in its first two dimensions (21.22% on Dimension 1 and 16.67% on Dimension 2). Most keywords are densely concentrated near the origin, whereas a small number of terms lie far from the center: educational robots and students at the far right of Dimension 1, educational robotics in the lower part of the plane, and project-based learning in the upper part, with primary schools, primary education, and education in intermediate positions. The map shows a single cluster, indicating one connected conceptual space rather than separate subfields.

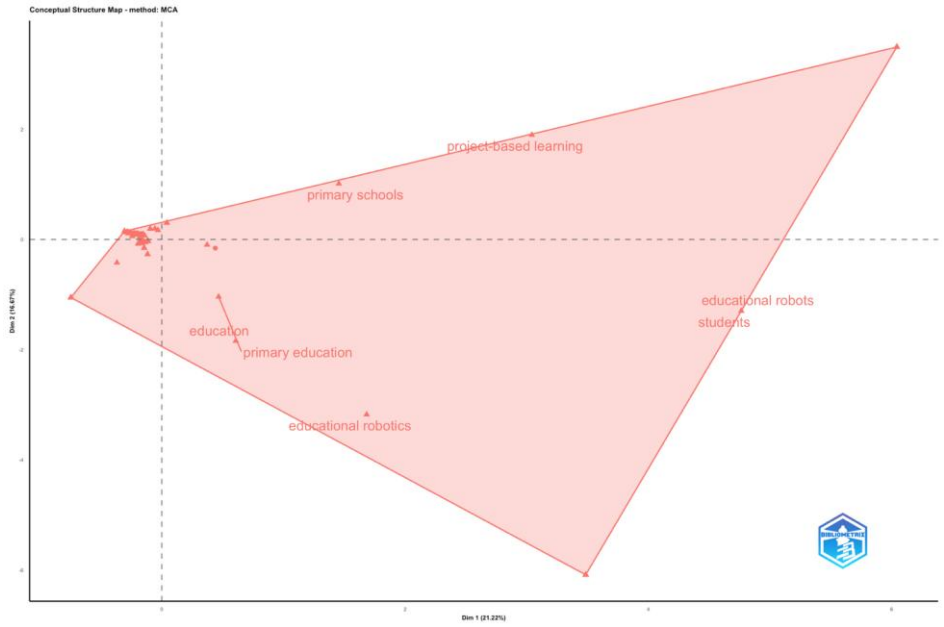


Figure 11. Factorial analysis (conceptual structure map, MCA)

Discussion

Growth, maturity, and citation impact

The findings indicate that research on STEM approaches in primary education is a young field in a phase of rapid expansion. The 31.8% annual growth rate and the concentration of 89.1% of the articles in the period since 2021 parallel the growth that Li et al. (2020) reported for STEM education research overall, and suggest that primary-level STEM has moved from the margins to a recognized research focus. The small absolute numbers, however, with a maximum of 12 articles in a year, mean that year-to-year fluctuations, such as the dip in 2025, should not be over-interpreted, particularly because 2026 was incomplete at data collection.

The citation pattern should likewise be read in light of time lags. The decline in average citations for the 2025 and 2026 cohorts most plausibly reflects the short period in which recent articles could accumulate citations rather than lower impact, which is consistent with the dataset's average document age of 2.69 years. The 2021 peak is strongly influenced by the single most cited article of that year, and impact overall is concentrated: ten articles account for about 63% of citations, and one article alone for roughly one fifth (98 of about 497). Notably, three of the ten most cited articles appeared in journals with an explicit technology focus (Journal of Computer Assisted Learning, Behaviour and Information Technology, and Education and Information Technologies), which suggests that the research with the greatest visibility connects primary STEM learning with educational technology.

Fragmentation and collaboration

The dispersion of sources, authors, institutions, and countries points to a field that has not yet consolidated around a stable core. That 43 of 48 sources published a single article is consistent with the long tail of scattered sources associated with Bradford's (1934) law of scattering, and that no author produced more than two articles fits the pattern predicted by Lotka's (1926) law, in

which most authors publish only once. The mix of leading outlets, spanning science education (Jurnal Pendidikan IPA Indonesia), technology-enhanced learning (Education and Information Technologies), general education (Frontiers in Education, Education Sciences), and sustainability (Sustainability (Switzerland)), shows that primary-level STEM research is communicated across several disciplinary communities.

Geographically, the field is genuinely global: the leading institutions are spread across Asia, Europe, and North America, and the four most productive countries, Türkiye, China, the United States, and Malaysia, produced 45.5% of the articles. Yet global participation has not translated into intensive international collaboration. Teams are fairly large (3.65 co-authors per article), but only 16.36% of the articles are internationally co-authored, and several productive countries, including the United States, Spain, Thailand, and Kazakhstan, show no multiple-country publications among their corresponding-author articles. The two Indonesian articles, both internationally co-authored, together with the presence of Jurnal Pendidikan IPA Indonesia among the leading sources, suggest that researchers in Indonesia are already connected to international networks and that national journals contribute meaningfully to the field.

Thematic structure and evolution

The thematic structure shows a field organized around a generic core and a set of specialized, technology-oriented streams. The basic themes, STEM education, primary education, and primary schools, define the boundaries of the field but are not yet developed in depth, as their lower density indicates. The motor themes show where conceptual development is strongest: educational robotics together with engineering and mathematics, and computational thinking together with students' STEM learning attitudes. This agrees with prior literature that identifies robotics and computational thinking as prominent vehicles for STEM learning in the early years (Benitti, 2012; Bers et al., 2014; Wing, 2006). The temporal analysis qualifies this picture. Educational robotics was the earliest dominant topic (around 2019), after which attention shifted toward mathematics and primary school students (2020 to 2021), engineering and teacher development (around 2022), integrated STEM education and primary schools (2023 to 2024), and finally learners' attitudes toward STEM, educational technology, and environmental awareness (2025 to 2026). The evolution therefore moves from tool-centered studies toward questions of disciplinary integration and teacher preparation, and more recently toward affective outcomes and the societal context of STEM learning.

Two further observations deserve attention. First, inquiry-based and project-based learning, and the cluster linking primary school teachers with STEM integration, are well developed internally but weakly connected to the rest of the field, as their niche position indicates. The MCA map points in the same direction, placing project-based learning at the periphery of the conceptual space. Pedagogical approaches and teacher-related questions thus appear to be studied apart from the technology-centered themes that dominate the motor quadrant, even though teachers' understanding and pedagogical design are central to STEM integration (Margot & Kettler, 2019). Second, environmental awareness lies in the emerging or declining quadrant and is also among the most recent trend topics, which supports reading it as an emerging theme. Together with the presence of Sustainability (Switzerland) among the leading sources, it may signal an incipient connection between primary STEM education and education for sustainability, a link directly relevant to the scope of this journal. Terms such as artificial intelligence and chatbots appear only marginally in the word cloud, but they indicate topics worth monitoring as generative technologies enter primary classrooms. The position of integrated STEM education in the emerging or declining quadrant, despite its mid-period trend, is ambiguous and may reflect overlapping keyword forms (such as integrated STEM and STEM integration) that divide a single concept across several clusters.

Implications and contribution

Theoretically, the study offers an empirical map of the intellectual structure of primary-level STEM research, showing that the field is cohesive in vocabulary but fragmented in authorship, outlets, and collaboration, and that technology-centered themes carry its conceptual development. Practically, the motor themes identify approaches with the most developed research base, such as educational robotics and computational thinking, that teacher educators can draw on when designing STEM courses for prospective primary teachers. The weak connection between pedagogical and technological themes suggests that teacher education should combine inquiry-based and project-based design with technology integration rather than treat them separately. For policy, the limited international collaboration and the dispersion of output suggest that funders and ministries could strengthen the field by supporting cross-national research consortia, shared instruments and datasets, and regionally relevant studies, including those published in national journals. The emerging attention to environmental awareness further suggests that curriculum policy can deliberately link primary STEM learning to sustainability goals.

The contribution of this study is a focused and reproducible bibliometric baseline for STEM approaches in primary education. Unlike broader reviews of STEM education (Li et al., 2020), it isolates the primary level and combines performance analysis with thematic and temporal mapping, so that the evolution of themes can be read alongside growth, authorship, and collaboration patterns.

Limitations and recommendations

Several limitations should be acknowledged. First, the dataset derives from one database and one document type (journal articles), so conference papers, books, and non-indexed local journals, including many Indonesian-language outlets, are not represented, and coverage differs between databases (Mongeon & Paul-Hus, 2016). Second, with 55 documents, indicators such as centrality and density, and the keyword-based clusters, are sensitive to small changes in the data, and the many keywords that occur only once limit the stability of the thematic structure. Third, citation indicators are time dependent, 2026 was incomplete at data collection, and the country analysis uses the corresponding author as a proxy for national contribution. Finally, the analysis is based on bibliographic metadata rather than full texts, so it describes what is studied and by whom but not how effective the STEM approaches are.

Future research could replicate the analysis with additional databases and document types and update it once 2026 is complete. Larger datasets would enable co-citation and bibliographic coupling analyses to identify the intellectual bases and research fronts of the field. Systematic reviews or meta-analyses of the motor themes, particularly educational robotics and computational thinking, could examine learning effects, while content analyses of the niche themes could clarify how inquiry-based and project-based learning and teacher development can be connected to technology-centered studies. Researchers are also encouraged to build cross-national collaborations, to study sustainability-oriented STEM learning in primary schools, and to monitor emerging topics such as artificial intelligence and chatbots.

CONCLUSION

This bibliometric analysis of 55 articles published between 2017 and 2026 shows that research on STEM approaches in primary education is a young but rapidly growing field. In response to the first research question, production grew at an annual rate of 31.8%, with 89.1% of the articles appearing since 2021, whereas citation impact peaked for the 2021 cohort and is concentrated in a small number of highly cited articles. In response to the second, productivity is widely dispersed across sources, authors, and institutions, with Türkiye, China, the United States, and Malaysia leading in corresponding-author output, and international collaboration is limited to 16.36% of the articles. In response to the third, STEM education, primary education, and

primary schools form the basic themes; educational robotics, engineering, mathematics, and computational thinking are the motor themes; inquiry-based and project-based learning and teacher-related themes are developed but isolated; and the focus has shifted from robotics toward integration, teacher development, learners' attitudes, educational technology, and environmental awareness.

These findings suggest priorities for researchers and policymakers: strengthening international collaboration, connecting pedagogical and teacher-related themes with technology-centered research, and developing the emerging link between primary STEM education and sustainability. The study provides a baseline that can be extended through multi-database, full-text, and effect-oriented analyses.

AUTHOR CONTRIBUTION STATEMENT

EF: Conceptualization, Methodology, Writing – original draft. **FS:** Data curation (Scopus/WoS database retrieval), Formal analysis. **RD:** Software (VOSviewer/Bibliometrix), Visualization. **BB:** Resources, Project administration, Validation. **AA:** Supervision, Interpretation of bibliometric trends, Writing – review & editing.

AI DISCLOSURE STATEMENT

During the preparation of this manuscript, the author used Claude to improve the language, grammar, and overall readability of the text. Following the use of this tool, the author reviewed and edited the content as necessary and assumes full responsibility for the final content, the interpretation of bibliometric data, and the accuracy of the published article.

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