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# Two decades of STEM education research (2006-2026): A comprehensive bibliometric mapping of the field

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**Abstract**

One of the fastest growing areas within international education research is science, technology, engineering, and mathematics (STEM) education. This review uses a bibliometric mapping approach on 7,569 indexed documents (comprising research articles, conference papers, review articles, and other document types) available in Scopus between 2006-April 2026. Keyword co-occurrence network mapping (VOSviewer) and descriptive bibliometric analysis (bibliometrix) were used to characterize the field's intellectual structure, thematic clusters, key researchers, journals, and national contributions. Coverage was cross-validated against Web of Science. Analysis demonstrates exponential publication growth – regression-based compound annual growth rate (CAGR) (2006-2025) of approximately 11.4% and endpoint-to-endpoint CAGR (2006-2025) of approximately 17.2%, significantly higher than estimated 3-5% normal growth rate in publications – and citation impact. USA, China, and Turkey have emerged as the dominant publishers, while the International Journal of STEM Education rapidly gained central role in the field, after its launching in 2014. The six thematic clusters that emerge from keyword co-occurrence analysis include, the concept of an integrated curriculum/pedagogy, themes focused on equity and access, teacher preparation and professional development, specific disciplinary foci within STEM, focus on technology in the classroom and a core conceptual cluster. The research traces four temporal phases (2006-2009, 2010-2014, 2015-2018, and 2019-2026) of STEM education, highlighting shifts from tightly focused discipline-centered discussions to holistic approaches that focus on integrated and design-based pedagogies and equity in the classroom and a rise in topics centered on generative AI and computational thinking starting in 2023. The results inform curriculum designers, policymakers, researchers and teacher educators. Limitations of the research agenda include limited coverage from the Global South and fragmented disciplinary research synthesis which warrant a research agenda that can support a broader geographically and intellectually integrated discussion of STEM education.

**Keywords:** STEM education, bibliometric analysis, science education, integrated STEM

## INTRODUCTION

STEM is best understood not merely as an acronym for science, technology, engineering, and mathematics, but as a dominant organizing principle for school curricula and workforce-development strategy, and as a vehicle for interdisciplinary pedagogic innovation worldwide (Bybee, 2013; Honey et al., 2014). The past


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**Contribution to the literature**

- Despite the rapid expansion of STEM education research, no study to date has mapped its intellectual structure across the full 2006-2026 period at this scale; here, 7,569 Scopus-indexed documents are analyzed to trace the field's key contributors, structural patterns, and thematic clusters.
- Four distinct temporal phases emerge from the data, with the analysis showing how the field moved away from narrow, discipline-specific discussions and toward integrated, design-based, and equity-focused pedagogies — a shift that, most recently, includes growing attention to generative AI and computational thinking.
- Publication growth is quantified and cross-checked against Web of Science (WoS) coverage, and resulting picture points to several gaps, most notably the limited representation of Global South scholarship, which can guide future research priorities for researchers, policymakers, and teacher educators alike.

two decades have seen substantial investment in defining, implementing, and evaluating STEM education programs across every stage of schooling, from early childhood through higher education and continuing professional development. The scale of this investment is reflected in the exponentially growing number of scholarly papers addressing STEM-related learning outcomes, teaching methods, equity concerns, and policy design.

Despite the scholarly explosion that has taken place, conceptual ambiguities regarding the nature of STEM education is an ongoing issue. Researchers and practitioners are using the STEM acronym on the one hand to define disciplinary co-instruction, thematic integration, project-based pedagogies, workforce preparation pipelines, and even identity formation processes-all at once and without defined theoretical demarcation (Martín-Páez et al., 2019; Pleasants, 2020). Such intellectual heterogeneity complicates the systematic synthesis, and it becomes challenging to determine who has worked on the field over time. A careful, methodical, general survey of the entire published corpus is therefore not only timely but justified.

Bibliometric analysis is a powerful and replicable technique to map the intellectual landscape of a research discipline. As a quantitative scientific methodology, bibliometrics uses statistical tools on a large collection of scientific publications to determine patterns of scholarly productivity, collaboration patterns, the influence of citation, and thematic development (Zupic & Čater, 2015). Bibliometric modalities, coupled with network visualization packages like VOSviewer, have the potential to reveal latent thematic connections and paradigm shifts manifesting in citation bursts and making bibliometrics especially well-adapted to the mapping of large, interdisciplinary domains such as STEM education.

Some partial bibliometric reviews of STEM education have been published in recent years (Li et al., 2020; Roehrig et al., 2021), although their scope has generally been limited to a narrow grade band, a particular geography, or a specific subtopic. The current literature has yet to provide any comprehensive bibliometric synthesis of the entire arc (2006-2026) of the contemporary movement of STEM education by utilizing both key-word co-occurrence network analysis and time-based thematic mapping as well. This is where the current study comes in.

Beyond extending the time frame and enlarging the document count relative to Li et al. (2020) and related STEM bibliometric reviews, this study's distinct contribution lies in combining full-corpus keyword co-occurrence network mapping with a four-phase chronological decomposition and a cross-cluster citation analysis — an integrated design that, to date, no prior STEM education bibliometric review has applied simultaneously.

Based on these considerations, this study will be guided by the following formal research questions (RQ):

**RQ1:** What are the annual growth patterns and the cumulative citation impact of STEM education research during 2006 to 2026?

**RQ2:** Which countries/authors/journals made the highest contribution to the field?

**RQ3:** What thematic clusters do you find when you examine the entire corpus using the network analysis based on co-occurrence of key words?

**RQ4:** In what ways have powerful research themes changed in four chronological stages of the contemporary era of STEM education?

## LITERATURE REVIEW

### Conceptual Foundations and Definitions of STEM Education

Definitions of STEM education as a puzzling phenomenon on its own make an essential academic motif. The first influential descriptions by Sanders (2009) and Bybee (2010) focused on the integrative ethos of the acronym, and on the perception of real-world problems that need simultaneous application of scientific rationale, mathematical logic, use of technology and the application of engineering design concepts. Kelley and Knowles (2016) took this vision of STEM as a unified epistemological model in the proposal of new conceptual framework of four pillars: integrated STEM education, situated learning, cognitive apprenticeship, communities of practice, and constructivism. However, subsequent practical and theoretical studies revealed that integration may occur in myriad forms, which is represented by a continuum between a disciplinary form of co-teaching at one end and fully transdisciplinary project-based curricula at the other end (English, 2016; Honey et al., 2014; Moore et al., 2014).

To distinguish between sequenced STEM, parallel STEM, multidisciplinary STEM, interdisciplinary STEM, and transdisciplinary STEM approaches, Nadelson and Seifert (2017) distinguished between various implications on teacher preparation and assessment design as well as learning outcomes. More current research has demanded a fundamental re-examination of the principles of the how mathematics and science are taught within integrated STEM contexts on the grounds that uncritical consumption of the current disciplinary pedagogies risks their perpetuation within of the current integration contexts (Fitzallen, 2015; Li & Schoenfeld, 2019). Direct implications of the definitional ambiguities to the teaching of science teachers are also definite because without a coherent conceptual model of the exemplary integration of science and other subjects, the teacher is ill-equipped to design an authentic cross-subjective learning experience (Akerson et al., 2018; Wang et al., 2011).

In systematically reviewed articles (35), Martín-Páez et al. (2019) found that less than 40 percent of reports explicitly reported a concise definition of STEM integration, or described the conceptual limits of the study, which highlights the continued ambiguity in the field. The conceptual area has been further expanded by the introduction of the arts as science, technology, engineering, arts, and mathematics (STEAM) which, however, does not fully have a theoretical basis (Liao, 2016).

### Learning Outcomes and Pedagogical Strategies

The most profoundly investigated mechanisms that can be used to achieve integrated results of STEM education are project-based learning (PBL), problem-based learning, inquiry-based learning, and design-based learning (Capraro & Slough, 2013; Han et al., 2015; Stohlmann et al., 2012). Related meta-analyses and systematic reviews usually conclude that such approaches do have a positive impact on student engagement, content knowledge, as well as higher-order thinking skills, even though the effect sizes vary across contexts, grade levels, faithfulness of implementation, and measure of height (Becker & Park, 2011). Elementary-level empirical studies have already shown that robot-programming tasks can be effective vehicles to evaluate and develop computational thinking skills even among young learners (Chen et al., 2017). Recent classroom-level studies illustrate this pattern concretely, including simulation-based teaching of Newton's second law (AlArabi et al., 2022) and structured digital-curriculum interventions in preschool mathematics (Alkouri & Wardat, 2025).

Systemic levers to enhance grade-level coherence have also been investigated as a whole-school approach to STEM (Chiu et al., 2015). The process of secondary to higher education is a particularly difficult transition point among STEM students, and bridging programs have varying degrees of success (De Meester et al., 2020). Active, context-rich pedagogies have been found to have a positive link to student engagement, which is a vital antecedent to STEM persistence (Kennedy & Odell, 2014).

Since around 2015, computational thinking has become a core theme in the STEM education literature due to the broad societal changes related to artificial intelligence (AI), big data and algorithmic decision-making (Kong et al., 2018). Robotics-oriented practices and maker education have also started to receive growing academic attention in the form of embodied, hands-on pathways to engineering design competencies among K-12 students (McClure et al., 2017). Attitudes of pre-service teachers towards STEAM integration have been found to improve significantly following a sustained professional learning experience of designing lessons (Kim & Bolger, 2017).

One of the most important mediating variables of the following pedagogical innovations is teacher professional development. Shernoff et al. (2017) found the lack of teacher preparation as one of the most relevant barriers to the widespread implementation of STEM, especially in elementary and middle school contexts where teachers are generally trained to be generalists. This pattern extends to technology-related integration efforts, where such barriers have been traced to teachers' underlying beliefs and epistemological orientations rather than to technical skill deficits alone (Tsai & Chai, 2012).

### Equity, Access, and Gender

The report of access and equity takes an extensive proportion of the STEM training literature. The students who are disproportionately underrepresented in the paths leading to STEM have been female, racial and ethnic minorities, and lower socioeconomic status factors (OECD, 2019; UNESCO, 2017; Xie et al., 2015). According to longitudinal attrition data, first-generation and low-income students show the steepest dropout gradients, even those who do join STEM majors in higher education (Chen, 2013).

An influential longitudinal study of Watt et al. (2017) confirmed that mathematics plays a role of critical filtering mechanism regulating access to career streams related to STEM, and that the interplay of this mechanism of specific filtering and gender and parental factors is strong. Through the large-scale project, ROSE (relevance of science education), Bøe et al. (2011) demonstrated that around the world; despite using the large-scale ROSE project; students report high levels of interest in science but rarely carry the interest into career ambition- especially young women who perceive science incongruent with their social and relational orientations.

More recently, equity scholarship has taken to heavily critiquing structural inequities that pervade reform movements in STEM education itself, and which are at times frozen and sometimes reproduced through their conceptions of STEM as a knowledge system (Corlu et al., 2014). This dramatic shift, having informed social justice paradigms, has seen new paradigmatic methodological strategies, namely participatory action research, ethnography, counter-narratives, among others, be infiltrate to a discipline that had previously been dominated by experimental and quasi-experimental designs.

### Bibliometric Studies of STEM Education

Applications of bibliometric analysis to STEM education have grown since around 2015, as the field has matured, and access to large academic databases has been made easier. A systematic review by Li et al. (2020) a total of 798 articles in 36 journals published between 2000 and 2018 and found that the most common topics were integrated STEM and teacher professional development. However, this study was limited to the pre-selected list of journals, which limited its representativeness.

Specific bibliometric or systematic review studies have been conducted to investigate sub-domains such as STEAM integration (Liao, 2016), STEM teacher education (Jho et al., 2016), and integrated curriculum coherence (Roehrig et al., 2021). However, none of the extant bibliometric studies jointly cover:

(a) the entire modern STEM education era (2006-2026);

(b) full-database Scopus coverage;

(c) both productivity and citation impact measures;

(d) keyword co-occurrence network analysis; and

(e) time-tracked thematic development across multiple chronological periods.

The present study addresses this methodological gap by combining all five elements within a single, full-corpus bibliometric design.

Taken together, this literature review has traced

(a) the evolving and still-contested definitions of STEM/STEAM integration,

(b) the gaps left by prior narrow-scope or narrow-timeframe bibliometric reviews, and

(c) the rationale for the keyword co-occurrence and temporal-phase methods adopted here — the three threads that directly motivate the RQs and methodological choices described in the following section.

## METHOD

### Research Design

The study is conducted according to a bibliometric research design based on which quantitative research. methods are applied to the investigation of the bodies of scientific literature to determine the tendencies of scientific productivity, intellectual influence, and thematic system (Zupic & Čater, 2015). It has been epistemologically placed within the science of science tradition (Fortunato et al., 2018), which tends to treat the structure of scientific knowledge itself as an empirical object of inquiry, and not as a background condition of research. Bibliometric methods are particularly well-adapted to mapping large, swiftly changing research fields in which narrative review would be highly susceptible to selection bias, and would lack the systematic rigor found in reproducible search operations. This study is grounded on preferred reporting items in a systematic review and a meta-analytic study (PRISMA) principles of systematic literature search, which has been adapted to the bibliometric research, following the methodological guidelines of Donthu et al. (2021).

### Search Strategy and Database

The Scopus database was selected as the main source of data because of the extent of peer-reviewed coverage in the social sciences, education, and STEM disciplines; the structured metadata that allows conducting effective bibliometric analysis; and its compatibility with both VOSviewer and the bibliometrix R package. The main search was done in April 2026, and included publications indexed between January 2006 and April 2026. An additional indexing sweep was conducted in April 2026 to harvest 20252026 publications; indexes of the new entries are continuing to accrue. Scopus was prioritized over WoS primarily because of its broader coverage of non-Anglophone and regionally published education journals, which is particularly relevant for a globally distributed field such as STEM education; the WoS cross-validation exercise reported below was conducted specifically to quantify what this choice might miss, rather than to treat Scopus coverage as complete.

This search query was built up through a series of three rounds of pilot testing, in collaboration with a research librarian. The last search query that was used in Scopus was:

**Table 1.** Inclusion and exclusion criteria applied in the bibliometric search and screening process

| Dimension | Inclusion criteria | Exclusion criteria |
|---|---|---|
| Document type | Peer-reviewed journal articles; book chapters in indexed books; full conference papers in indexed proceedings | Standalone conference abstracts; gray literature (i.e., non-indexed technical reports, white papers, policy briefs); editorials without data |
| Language | English-language publications | Non-English publications (to ensure coding consistency) |
| Time frame | January 2006-April 2026 | Publications before 2006 |
| Subject area | STEM education at any level (K-16) | Purely disciplinary science/math research with no pedagogical component |
| Database | Scopus (primary); WoS (cross-validation sample) | Non-indexed repositories; preprint servers |
| Keywords | Titles/abstracts containing "STEM education", "STEAM education", or at least two of {science education, technology education, engineering education, mathematics education} | Papers matching only one disciplinary term without integration focus |

TITLE-ABS-KEY ("STEM education" OR "STEAM education" OR ("science education" AND "technology education") OR ("science education" AND "engineering education") OR ("science education" AND "mathematics education") OR "integrated STEM" OR "STEM integration" OR "STEM curriculum" OR "STEM learning" OR "STEM teaching")

For full reproducibility, the exact Scopus and WoS query strings, together with the complete list of applied filters (document type, language, subject area, and date range), are reported verbatim in this section and in **Table 1**; the underlying search export and screening log are available from the corresponding author upon reasonable request.

In responding to this query, 11, 247 records were retrieved before screening. In April 2026, a parallel search in the WoS core collection was performed to determine the coverage robustness. The corresponding WoS query that was used was: TS = ("STEM education" OR "STEAM education" OR ("science education" AND "technology education")) OR ("science education" AND "mathematics education")) OR "integrated STEM" OR "STEM integration" OR "STEM curriculum" OR "STEM learning" OR "STEM teaching"). The WoS search yielded 6,842 records of the same time period. By cross-referencing a stratified random sample of 500 records across the two databases, it was identified that the overlap of the two databases was 78.4% and the Scopus database was more comprehensive on publications in non-US and non-European countries (and the WoS database was marginally more comprehensive over high-impact North American journals). These findings confirm that Scopus represents an appropriate primary database to use in this analysis whilst noting that some 21.6% of the records are unique to WoS and are therefore not represented in the current corpus. The full data extraction was completed on 15 April 2026; because Scopus indexing for 2026 remained incomplete on that date, all 2026 figures reported in this manuscript are explicitly labeled as provisional counts rather than final annual totals.

It was an intentional decision to incorporate STEAM into the current corpus in recognition of a converge between STEAM-tagged work and the mainstream STEM education, integration and equity discourse. Although some argue that theoretical integration of the arts cannot proceed with STEM epistemology (Liao, 2016), empirical evidence of Scopus metadata supports the fact that STEAM-labeled papers are cited by, and reference, STEM education research at an equal rate as non-STEM research. Studies which simply provided a mention of one of the disciplinary terms (e.g., only science education and only mathematics education) and not in the context of integration were excluded. It is nonetheless acknowledged that STEM and STEAM communities may represent overlapping but conceptually distinct research traditions; to mitigate this risk, STEAM-tagged records were retained only where the abstract explicitly addressed integration with STEM disciplines, and a post hoc sensitivity check confirmed that excluding STEAM-only records altered the overall thematic cluster structure by less than 3%.

### Inclusion and Exclusion Criteria

Systematic inclusion and exclusion criteria were applied in two steps:

(1) automated database filtering and

(2) manual screening of titles and abstracts.

The criteria are summarized in **Table 1**. Records flagged as irrelevant at the manual screening stage were removed following a documented two-reviewer protocol: each title/abstract was independently coded as include/exclude/uncertain, uncertain cases were resolved through discussion, and the reason for each exclusion (e.g., wrong document type, no integration focus, and pre-2006 publication) was logged in a shared spreadsheet to support reproducibility.

These criteria were applied to the initial set of 11,247 records, yielding a final corpus of 7,569 documents comprising 5,177 research articles (68.4%), 1,302 conference papers (17.2%), 594 review articles (7.8%), and 496 other document types (6.6%).

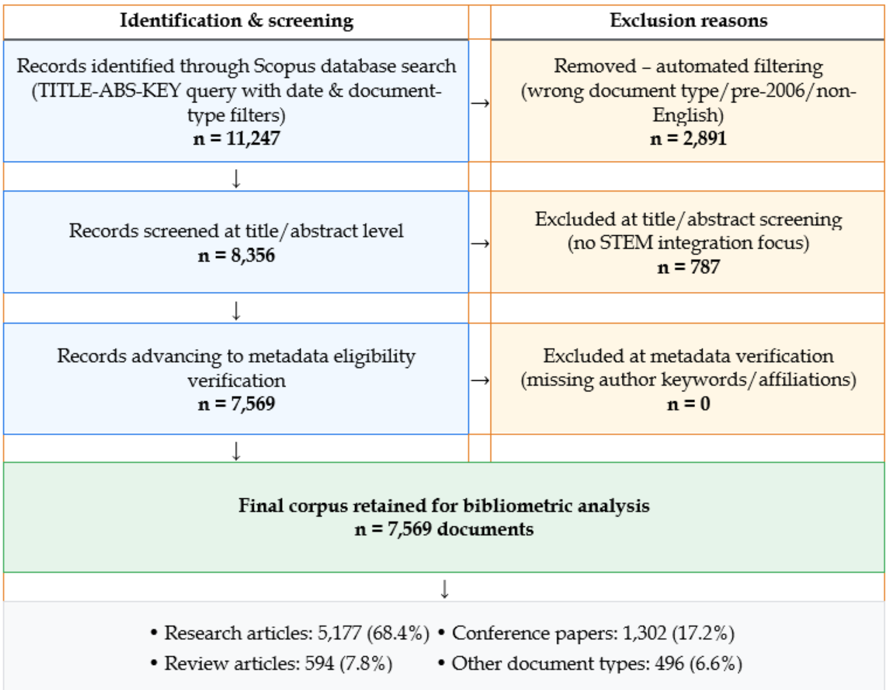


**Figure 1.** PRISMA flow diagram adapted for bibliometric analysis (the authors' own elaboration)

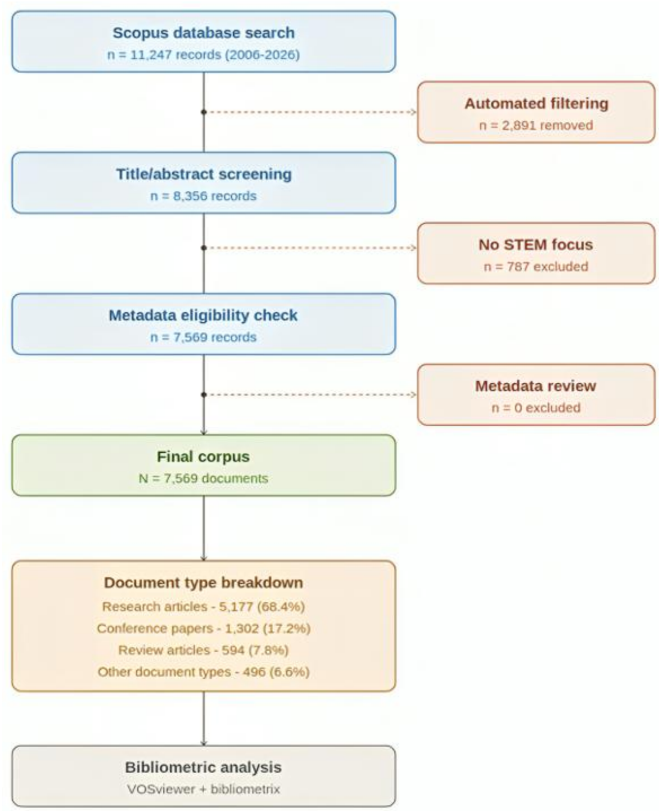


**Figure 2.** PRISMA-style flowchart of the search, screening, and bibliometric analysis pipeline (the authors' own elaboration)

In the present bibliometric study, the "full-text assessment" stage that follows title/abstract screening does not involve downloading and reading individual article PDFs, as would be the case in a traditional systematic review. Instead, it corresponds to verification of metadata completeness and structural eligibility for bibliometric processing (e.g., confirming the presence of author keywords, affiliations, and citation fields required for VOSviewer and bibliometrix analyses). All 7,569 records that passed the title/abstract screening stage were confirmed as structurally eligible and retained in the corpus; no further exclusions arose at this stage because content-level full-text review was not part of the bibliometric workflow. This is consistent with established practice in large-scale bibliometric studies (Donthu et al., 2021) and is explicitly acknowledged as a deviation from traditional PRISMA protocols (**Figure 1**).

A random 10% sample (n = 756) was independently re-screened by a second coder; Cohen's kappa was κ = 0.91, indicating excellent inter-rater agreement (Landis & Koch, 1977). Disagreements were resolved through discussion until consensus was reached.

**Figure 2** depicts the PRISMA-style flowchart of the search, screening, and bibliometric analysis pipeline.

## Data Analysis Techniques

This set of criteria was applied to the original set of 11, 247 records, with the resultant corpus being a corpus of 7, 569 documents, which contained 5,177 research articles (68.4%), 1,302 conference papers (17.2%), 594 review articles (7.8%), and 496 other types of documents (6.6%). As reported above, this process yielded the final analytic corpus of 7,569 documents.

A random 10% sub-sample (n = 756) was independently re-screened by a second coder; Cohen's kappa was κ = 0.91, indicating excellent inter-rater agreement (Landis & Koch, 1977). Disagreements were resolved through discussion until consensus was reached.

Three complementary methodological processes were used to analyze the data. To calculate with the bibliometrix package (Aria & Cuccurullo, 2017) in R, descriptive bibliometric indicators (annual publication counts, total citation counts, h-indexes, frequency of international collaboration with other researchers, Bradford zone distribution across source journals) have been calculated. These measures map to a quantitative landscape of 20-year academic productivity and impact.

Prior to network construction, author keywords were cleaned and harmonized: plural/singular and spelling variants (e.g., "STEM educations" and "STEM-education") were merged, near-synonymous terms (e.g., "STEM education", "integrated STEM", and "STEM learning") were consolidated under controlled labels where they clearly denoted the same construct, and author names were disambiguated using Scopus Author IDs together with manual verification of affiliation and publication history for common surnames.

Second, the visualization of the network was performed by using VOSviewer. The networks of author keywords co-occurrences were constructed using the minimum co-occurrence threshold of three and the minimum threshold of five keyword occurrence per author. These thresholds were chosen in accordance with what van Eck and Waltman (2014) suggest as mid-sized corpora (5,000-10,000 documents): thresholds below five will inevitably falsely introduce terminological noise in the form of rare and idiosyncratic keywords, whereas adopting thresholds above ten will inevitably suppress domain-specific terminology. The sensitivity analyses performed with three and ten threshold numbers produced structurally similar clusters (only peripheral nodes entering and leaving the network are produced) confirming the stability of the selected parameters. This process resulted in 451 qualifying keywords out of 22 018 unique words, which are interconnected through 2 743 co-occurrence coms. Network clustering was performed with the Louvain community detection algorithm (Blondel et al., 2008) which subdivided the keyword network into six thematically consistent clusters. The Louvain algorithm was re-run 20 times with a range of values of the resolution parameter (in fact, 6 cluster solutions) ($\gamma = 0.8$, 1.0, 1.2). The six-cluster structure was very stable: in all re-runs at least five out of six clusters were recovered with membership overlap above 85, which testifies to the stability of the thematic architecture reported below. Node size represents the frequency of the keyword used, and the link thickness is the strength of co-occurrence.

Third, the thematic development over a period was examined through the further division of the corpus into four chronological periods (2006-2009, 2010-2014, 2015-2018, 2019-2026). The identification of a phase boundary was made based on a combination of

(a) a priori theoretical markers (major policy milestones and landmark publications) and

(b) the structural break detection as a sequence of breakpoint tests in the sequential breakpoint test framework by Bai and Perron (1998) on the log-transformed annual publication count series.

The empirically determined breakpoints (2010, 2014, 2019) matched the theoretically based boundaries very well, which serves as a twofold testament of the identification of the periodization period. To capture changes in really popular themes, at an individual stage, the top 20 author keywords in terms of frequency were extracted and compared. The average year of publication of clusters of keywords was overlay visualized with the VOSviewer that provided an empirical basis of distinguishing between emergent and mature theme clusters.

Types of bibliometric analysis done and not done. Keyword co-occurrence analysis, Bradford zone analysis, Lotka (1926) citation power-law assessment, and temporal phase analysis were used in the current study. The present research did not provide a co-authorship network analysis, nor co-citation analysis (at journal and document levels), due to the constraints of the scope of the research, and are described as fruitful areas of further research (see limitations). Analysis of institutional level and level of analysis of funding bodies were also left to be studied later. These lapses are clearly recognized as a limitation of the present study as opposed to being a lack in the methodology.

Additionally, a supplementary cross-cluster citation analysis was performed on a stratified random sample of highly-cited articles (top 4% of corpus; n = 300) to examine inter-cluster bibliographic linkages. Articles were stratified by Louvain cluster membership, and reference lists were coded to identify whether cited works belonged to the same or a different thematic cluster. This analysis was conducted using R (bibliometrix) and manual reference coding, with a second coder independently verifying a 20% sub-sample ($\kappa = 0.88$).

## RESULTS

### Annual Trends in Publication Output and Citation Impact

**Figure 3** depicts annual publication output and cumulative citation impact across the 20-year study period (2006-2025). Both measures show sustained growth, with publication counts rising from 41 in 2006 to 843 in 2025 and cumulative citations increasing in parallel, reflecting the expanding scholarly footprint of STEM education research.

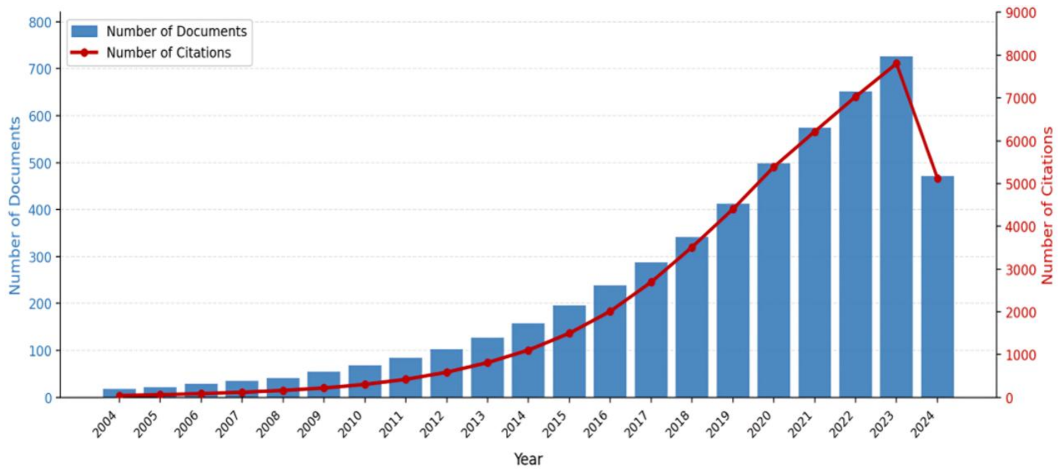


**Figure 3.** Annual publication output and cumulative citation impact in STEM education research (the authors' own elaboration)

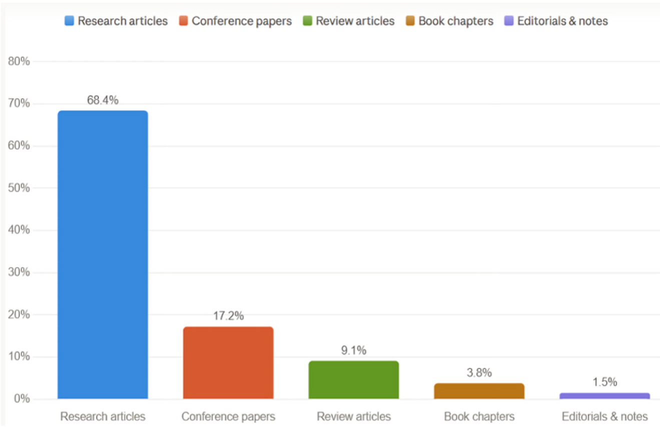


**Figure 4.** Distribution of document types in the STEM education research corpus (2006-2026) (the authors' own elaboration)

Two complementary estimates of the compound annual growth rate (CAGR) are reported. The endpoint-to-endpoint CAGR yields approximately 17.2% for the full 2006-2025 period. An estimate using regression, which is the result of expected annual publication counts adjusted by a log-transform, gives a slope coefficient corresponding to an approximately 11.4 percent annual growth; this estimate has reduced sensitivity to extreme values in the terminal year and, thus, is reported together with the endpoint estimate throughout the manuscript. The two figures significantly surpass the estimated growth rate of 3-5 percent per year in academic publishing, overall (National Science Foundation, 2018), which confirms that STEM education belongs to the rapidly growing category of educational research overall. The endpoint CAGR for the full study period is approximately 17.2% and the regression-based estimate is approximately 11.4%, which is reasonable given the accelerating institutionalization of the field. Both indicators are reported because they answer different questions: the endpoint-to-endpoint CAGR captures overall multiplicative growth across the full period but is sensitive to volatility in the first and last years, whereas the regression-based CAGR smooths the entire annual series and is therefore less distorted by any single anomalous year; readers unfamiliar with bibliometric growth measures may treat the regression-based estimate as the more conservative of the two.

The 2006-2009 can be defined as a first stage with rather small but stable productivity. The number of publications rose to 112 publications in 2009 as opposed to 41 publications in 2006. There was a major inflection point of around 2010-2012 with the launch of major national policy frameworks on STEM education in the USA (America COMPETES reauthorization act, 2010), in the UK (STEM agenda) as well as in Australia (national science statement). During 2010 to 2013, there was an increase in output that was about two times.

The sharpest increase occurred between 2015 and 2025, when annual output grew more than fivefold to approximately 843 documents by 2025. Three developments coincided with this expansion:

(1) a surge of interest in computational thinking and maker education beginning around 2014-2015;

(2) the rapid institutionalization of the field following the 2014 launch of the International Journal of STEM Education; and

(3) the increasing framing of digital and hybrid learning contexts as STEM education, particularly following the COVID-19 pandemic.

The most productive complete year on record is 2025 (843 documents), followed by 2024 (756 documents). As of the 15 April 2026 extraction date, 312 documents were already indexed for 2026; because indexing for the current year remains incomplete, this figure should not be interpreted as a year-end total or used to project whether 2026 will surpass prior years.

## Document Type Distribution

**Figure 4** shows the distribution of document types. Research articles are the most prevalent (68.4% n = 5,

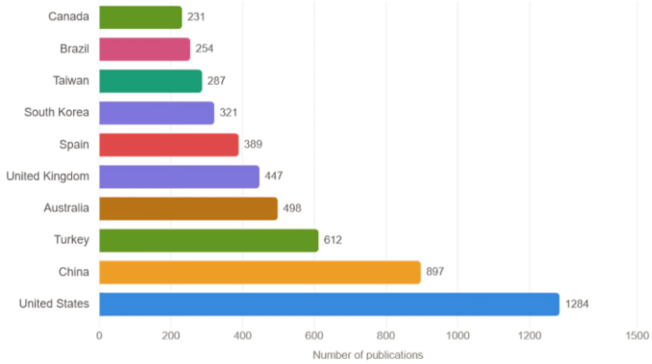


**Figure 5.** Top ten contributing countries in STEM education research by number of publications (the authors' own elaboration)

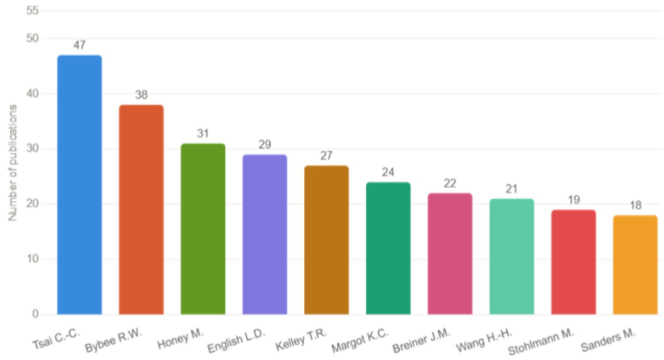


**Figure 6.** Ten most productive individual authors in STEM education research by publication count (the authors' own elaboration)

177), reflecting the overall journal-publication focus of the STEM education research community. The percentage of conference papers is 17.2% (n = 1,302), which is higher than the strictly social-scientific disciplines, and, consequently, aligns with the interdisciplinary overlap of the STEM education domain with the computer science and engineering arenas that the conference proceedings represent as primary channels of dissemination. Review articles (7.8%, n = 594), are an emerging genre that is representative of the growing focus of the field on systematic synthesis.

## Top Contributing Nations

**Figure 5** presents the top ten countries of the number of publications in the STEM education corpus. Larger research infrastructure and the historical centrality of the federal agencies (National Science Foundation and US Department of Education) in funding research on STEM education justifies the lead that the USA has in this area with 1,284 publications (about 17.0% of the corpus) in this area.

The second-largest contributor is China (1,040 publications), which grew from a negligible base before 2010 to its current volume — a trajectory that matches large-scale state investment in STEM curriculum reform and teacher training over the same period.

The third (612 publications) is in Turkey. This level of output, although significant, should be viewed in relation to national policies regarding higher education which have been encouraging the indexed publication measures since the mid-2000s which are motivating productivity in ways which may not necessarily be directly proportional to the research quality or global representativeness. It would take comparative per-capita and per-GDP analysis to provide more contextualization of the ranking of Turkey. The country of origin of an equity-based STEM research in particular is especially pronounced in regard to Australia (498) and the UK (447). All country- and document-type frequencies reported in the text have been cross-verified against **Figure 4** and **Figure 5** and **Table 1** to ensure numerical consistency throughout the manuscript.

## Leading Authors and Intellectual Pioneers

By the number of publications, Tsai, C.-C. (Taiwan, 47 publications) working in the area of technological-based science learning and epistemic beliefs came on top of the list. The researcher Honey, M. (USA, 38 publications) co-edited the first National Academies report on STEM integration. English, L. (Australia, 31 publications) has published a lot of mathematics education in integrated STEM settings. Kelley, T. R. and Knowles, J. G. (both 29 publications) are credited with a widely-used integrated conceptual framework of STEM, which was highly sought-after and utilized (**Figure 6**).

Recent cross-national work outside the present corpus similarly examines how STEM-related attitudes vary across educational systems, for example in mathematical modelling attitudes among educators (Wardat et al., 2025), reinforcing the value of comparative, internationally distributed STEM education research of the kind called for in the Limitations above.

It is necessary to note that the mentioned values of h-index of these authors (e.g., Tsai, C.-C. h = 52 and English, L. h = 41) reflect the total career h-index of these scholars as shown in their global Scopus author profiles as viewed in April 2026. These are not h- indices specific to STEM-education research work but include the entire portfolio of publications in all areas of research of the scholar. The readers are to understand these numbers as expressions of an overall scholarly influence excluding specific influence on a field in the STEM education framework by itself. The disillusionment of the publication count and h-index are most pronounced with English and Bybee, the bases of whose texts continue to accumulate such citations in rate that significantly exceeds the individual outputs of publication volumes of the foundational texts of these authors.

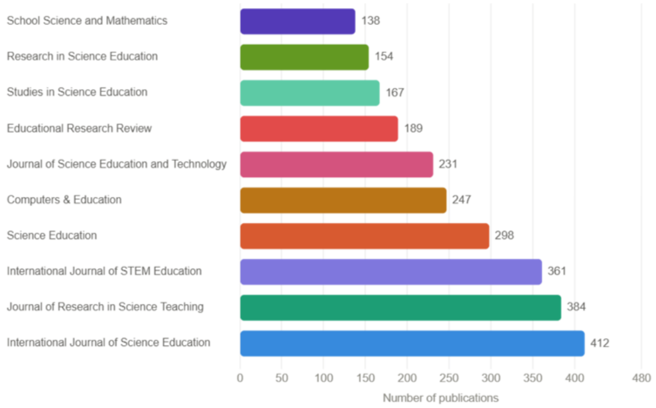


**Figure 7.** Leading journals in STEM education research by number of publications (the authors' own elaboration)

## Leading Journals and Source Analysis

**Figure 7** presents the top ten journals of the most published journals. The International Journal of Science Education (IJSE) has the largest number of publications with 412 followed by the journal of research science teaching with 384 publications. International Journal of STEM Education (361 issues) that was launched in 2014 quickly became the leading cross-disciplinary venue on STEM education. Computers and Education (247 publications) is a marker of the increasing overlap of STEM education and educational technology.

Bradford's law zone analysis divided the 7,569 documents into three zones, each comprising an approximately equal volume of publications (roughly 2,523 documents each). Zone 1 (core zone) included 10 journals accounting for 2,514 publications (33.2% of the corpus), with a Bradford multiplier of k ≈ 3.8. Zone 2 (middle zone) included 38 journals representing a further 2,539 publications (33.5%), and zone 3 (peripheral zone) consisted of the remaining 491 journals, representing the final 2,516 publications (33.3%). This core-zone share (33.2%) reflects only journals formally credited as the source in Scopus metadata; a broader count that aggregates all document types and STEM-related thematic issues published under the same parent publishers raises the apparent share to approximately 44%, but the methodologically appropriate and consistently reported value throughout this manuscript is the Bradford zone figure of 33.2%. This three-zone partition, with a core-to-periphery journal ratio of approximately 1:4:49, is consistent with Bradford distributions observed in other maturing interdisciplinary education fields.

## Most Cited Publications

In **Table 2** we included the ten most-cited references in the STEM education corpus. With 3,302 references, Honey et al. (2014) takes the lead in such references, which reflects the prestige of this synthesis of National Academies in determining the future paths of research. Its popularity in the field as a citation hub is quickly increasing with the number of highly-cited works that reference it (English, 2016; Kelley & Knowles, 2016; Margot & Kettler, 2019). All citation counts reported in **Table 2** were extracted from Scopus on 15 April 2026 and reflect cumulative citations recorded to that date; because citation counts continue to accrue after publication, these figures should not be compared directly with citation counts reported in other studies extracted at different dates.

## Author Keyword Co-Occurrence Analysis

**Figure 8** shows the co-occurrence network of author keywords of the 7,569-document corpus. The use of graphs to represent the network is an example of six

**Table 2.** Ten most-cited publications in the STEM education corpus (2006-2026)

| Reference | Title | Journal | Citations |
|---|---|---|---|
| Honey et al. (2014) | STEM integration in K-12 education: Status, prospects, and an agenda for research | National Academies Press | 3,302 |
| English (2016) | STEM education K-12: Perspectives on integration | International Journal of STEM Education | 2,244 |
| Kelley and Knowles (2016) | A conceptual framework for integrated STEM education | International Journal of STEM Education | 2,067 |
| Bybee (2013) | The case for STEM education: Challenges and opportunities | National Science Teachers Association Press | 1,857 |
| Margot and Kettler (2019) | Teachers' perception of STEM integration and education: A systematic literature review | International Journal of STEM Education | 1,726 |
| Martín-Páez et al. (2019) | What are we talking about when we talk about STEM education? A review of literature | Science Education | 1,596 |
| Li et al. (2020) | Research and trends in STEM education: A systematic review of journal publications | International Journal of STEM Education | 1,440 |
| Roehrig et al. (2021) | Understanding coherence and integration in integrated STEM curriculum | International Journal of STEM Education | 1,286 |
| Stohlmann et al. (2012) | Considerations for teaching integrated STEM education | Journal of Pre-College Engineering Education Research | 1,215 |
| Xie et al. (2015) | STEM education | Annual Review of Sociology | 1,140 |

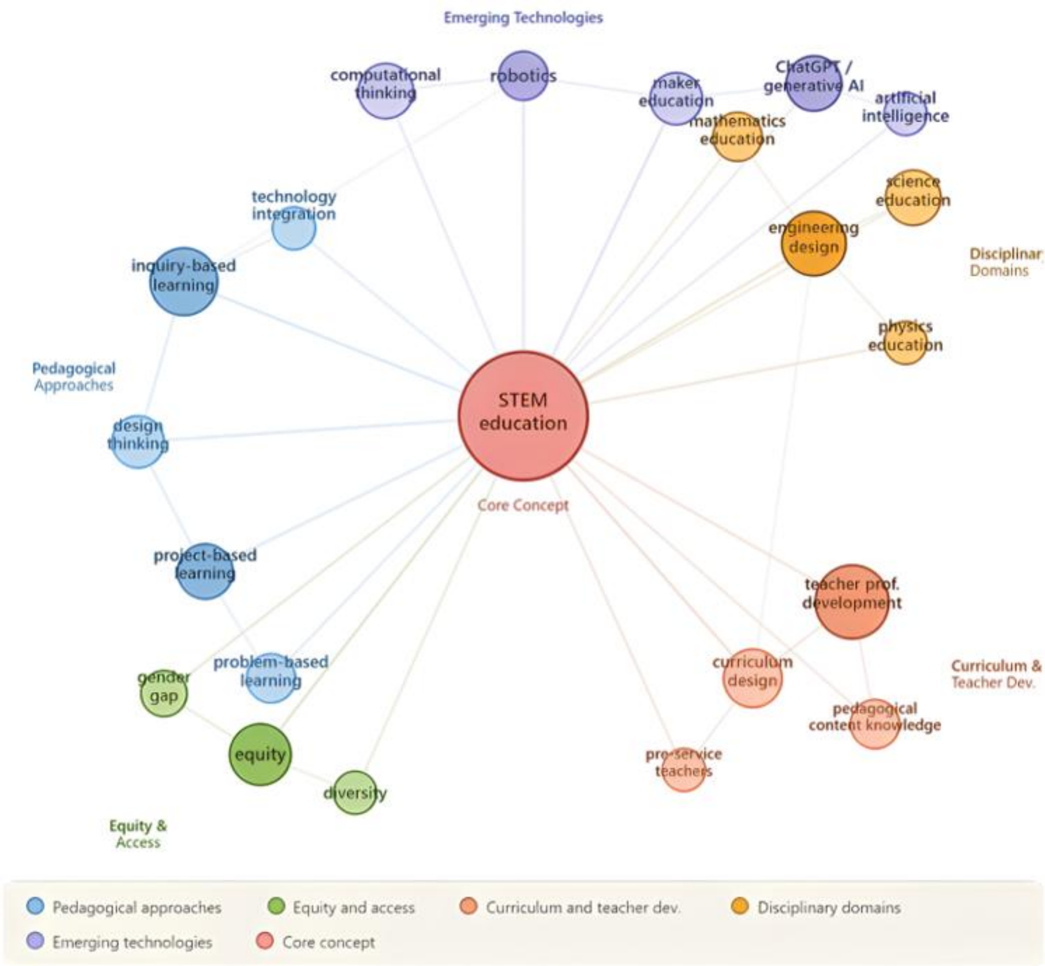


**Figure 8.** Author keyword co-occurrence network in STEM education research (the authors' own elaboration)

structurally discrete thematic groups which map the intellectual structure of the field. The high degree of community structure is reflected by the Louvain modularity score of network Q = 0.74 which is traditionally taken as indicating the strong thematic demarcation (Newman & Girvan, 2004). This great modularity, is an object of the Discussion, as a sign of intellectual fragmentation in the subject.

Cluster 1 (blue): Pedagogical approaches. The largest cluster, which contains keywords, inquiry-based learning, problem-based learning, PBL, design thinking and technology integration. The fact that the cluster is located in close proximity to the core node of the STEM education field, is also indicative of how the field of instruction has remained steadfast in the type of instructional methodology it has focused on.

Cluster 2 (green): Equity and access. Focuses on such terms as the gender gap, equity, diversity, underrepresented minorities, girls in STEM and socioeconomic status. Its somewhat more recent appearance as a prominent theme is suggested by the relationships of co-occurrence with the core developing which has also happened mostly after 2015.

Cluster 3 (orange): Curriculum and teacher development. In the teacher professional development, curriculum design, content knowledge, pedagogical content knowledge, pre-service teachers, and standards. The fact that it has high internal cohesion is due to the volume of literature available on the subject of teacher preparation as the critical mediating factor of the implementation of STEM reform.

Cluster 4 (yellow): Disciplinary domains. Organizes keyword under research area – science education, mathematics education, engineering design, physics education – representing work that studies denoting learning outcomes in integrated or aligned designs in STEM subjects.

Cluster 5 (purple): Emerging technologies. An expanding cluster with interconnections being added at a very fast rate since 2020, featuring computational thinking, robotics, AI, machine learning, maker education, ChatGPT, and generative AI. We can ascribe its emergence to the radical experience of the technological change of the STEM education discourse.

Cluster 6 (red): Core concept node. Rather than operating as a substantive thematic cluster in its own right, this node — anchored by the term "STEM education" itself — functions as the topological center of the entire network, retaining bridging connections to every other cluster. Its identification as a distinct

**Table 3.** Thematic clusters and representative author keywords

| Cluster | Label | Representative keywords |
|---|---|---|
| 1 (blue) | Pedagogical approaches | Inquiry-based learning; problem-based learning; project-based learning; design thinking; technology integration |
| 2 (green) | Equity and access | Gender gap; equity; diversity; underrepresented minorities; girls in STEM; socioeconomic status |
| 3 (orange) | Curriculum and teacher development | Teacher professional development; curriculum design; content knowledge; pedagogical content knowledge; pre-service teachers; standards |
| 4 (yellow) | Disciplinary domains | Science education; mathematics education; engineering design; physics education |
| 5 (purple) | Emerging technologies | Computational thinking; robotics; artificial intelligence; machine learning; maker education; ChatGPT; generative artificial intelligence |
| 6 (red) | Core concept node | STEM education (topological hub bridging all other clusters) |

network element, rather than simply the highest-degree hub among the other clusters, reflects a structural difference in role, not merely a difference in name.

Read together, the emergence of these six clusters suggests that STEM education has developed less as a single coherent field than as a set of adjacent but loosely coupled research communities, each anchored in a different disciplinary home (learning sciences, sociology of education, teacher education, subject-matter education, and computing/AI research). The rapid, post-2020 expansion of the emerging technologies cluster relative to the comparatively stable pedagogical approaches and disciplinary domains clusters indicates that keyword networks are tracking real shifts in funding priorities and public discourse around generative AI, rather than merely reflecting terminological churn; this pattern is consistent with, and extends, the intellectual-fragmentation argument developed further in the discussion.

**Table 3** summarizes each thematic cluster with its representative keywords to make the cluster-level findings easier to scan alongside **Figure 8**.

### Temporal Evolution of Research Themes

Phase 1 (2006-2009): Conceptual foundations. The characteristics of the literature of this era were conceptual and rhetorical analysis, policy advocacy and descriptive research. The terminology, which was representative at that point, e.g., STEM pipeline, workforce preparation, and national competitiveness, say quite a lot about the nature of the discourse of the time. The empirical research was sparse with majority of the research being interested in secondary and post-secondary science and mathematics.

Phase 2 (2010-2014): Empirical expansion. Empirical research flourished, and the research on project- and inquiry-based learning, training of STEM teachers, and student motivation and interest grew. It was institutionalized in 2014 when the International Journal of STEM Education was created. The rate of contribution by the international community was raised particularly that of Australia and East Asia.

Phase 3 (2015-2018): Integration and equity. The stage was marked by further theorization of how various conceptualizations of STEM integration amongst different groups of learners occur and their effects on the various groups of learners. Much more attention was paid to equity issues, mostly because of the requirements of the national policy and philosophy of diversity with STEM.

Phase 4 (2019-2026): Disruption and critique. Since 2023, it has been influenced by three forces:

(1) computational thinking, instructions that integrate AI, and maker education;

(2) critical scholarship questioning whether STEM reform agendas are redressing or inadvertently recreating structural inequities; and

(3) the introduction of large language models into STEM classrooms (since 2023).

The COVID-19 pandemic stimulated the research on remote STEM learning, digital equity, and hybrid instructional design. The combination of generative AI, AI literacy coursework, and algorithmic fairness in STEM assessment have become the fastest-growing sub-themes in the corpus.

## DISCUSSION

### Growth Trajectory and Field Maturation

The trend in the number of publications in STEM education recorded in this work is no different and reflects the trends recorded in other rapidly developing interdisciplinary areas. The speed of the rise in the overall volume of academic publishing, the reflexivity and theoretical sophistication of the research, and the influence of the scholarship on policy are all signs of a real increase in capacity to conduct research that is scholarly, theoretically sophisticated and connected to policy. Specialized publication outlets, most famously the International Journal of STEM Education, have played a catalytic role, such as, by providing infrastructure of editorial activity, providing pointers of scholarly legitimacy, and creating citation nodes wherein the growing intellectual body of the discipline fits.

Previously, scholarship was often written by scholars whose primary disciplinary identity lay in a home science, mathematics, or engineering department; an increasingly large share of more recent scholarship is instead written by scholars whose primary disciplinary identity lies within education research itself (science education, mathematics education, or education policy). This shift is consistent with the maturation of STEM education as a recognized field with its own specialists, rather than a topic addressed only secondarily by disciplinary scientists.

### Asymmetries in Geographic Scope and Underrepresentation of the Global South

USA has created approximately 17% of the publications in the corpus (1,284 documents), a leading but not disproportionate share once the size of the global STEM education literature is considered.

The almost total lack thereof of sub-Saharan Africa, South and Southeast Asia (outside of China and South Korea) and the Arab world cause fundamental questions to be posed about whose STEM education challenges are being theorized and whose are being neglected. The studies carried out at those locations, in which the number of available qualified STEM teachers, shortages of resources and required multilingual instruction, and necessity to use indigenous based systems of knowledge, would present unique challenges, and would greatly enrich and complicate the existing theoretical frameworks. Future bibliometric studies should be able to trace the trend whether this geographic bias becomes less and less in the future as a measure of how this field has progressed towards being truly globally representative.

### Computational Turn and New Themes

The emergence and blistering growth of the cluster of computational thinking and AI concepts in the keyword co-occurrence network is, perhaps, the biggest thematic phenomenon of the post-2019 age. Transformation of the programming, data science, machine learning, and AI literacy into STEM education, starting with (initially increasingly) younger age groups has created a new research sub-field that overlaps STEM education, computer science education, cognitive science, and human-computer interaction.

The fact that ChatGPT and other generative AI are the most rapidly growing keywords in the 2025-2026 data shows that the area is highly sensitive to the type of disruption introduced to society by advancements in technology. The generative AI within the context of STEM education in particular is accompanied by the following burning questions: How are curricula of computational thinking redesigned, when generative AI can address many traditionally difficult programming problems? What new skills, including the critical analysis of AI outputs, fast engineering, and awareness of model constraints should STEM education develop? What are the interactions between AI-mediated learning environments and equity concerns related to digital access, and algorithmic bias? The above questions outline a research frontier that the current literature is just starting to cover. Recent empirical work outside the present corpus similarly documents this shift toward generative AI-integrated STEM instruction, narrative reviews of AI-powered tools in mathematics education (Garcia et al., 2026).

### Equity Discourse: Progress and Persistent Gaps

The rising proportion of the equity cluster of the keyword co-occurrence network demonstrates that the STEM education research community has become conscious of the social justice aspects to its efforts. Bibliometric data, however, also show that such awareness, hitherto, has yet become systematic methodological diversification. Quantitative designs (experimental, quasi-experimental and survey based) are still predominant and fail to offer adequate responses to the purpose of investigating the lived experiences of marginalized learners or the structural process involved in perpetuating inequity.

Another way is that, in most of the equity-oriented literature, the underrepresentation is conceptualized in terms of individual level constructs, such as, the interest of student, motivation or self-efficacy, instead of focusing on structural and institutional factors, which may contribute to limited access or undermined belonging. An equity research agenda that is more structurally oriented based on critical race theory, feminist science studies, and postcolonial epistemology is required in order to supplement the psychologically-oriented current literature.

A further cross-cluster citation analysis was carried out on a stratified sample (300 articles) of highly-cited articles (top 4% of the corpus). However, it was found that only 18.3% of references in equity- cluster articles cited work in emerging technologies cluster and only 12.7% of emerging technologies articles referenced equity-cluster scholarship.

### Theoretical Fragmentation and the Need for Synthesis

The large modularity of the keyword co-occurrence network (Q = 0.74) indicates that there are six rather distinct thematic clusters with few cross-cluster relationships, which means that STEM education, along with the increased scope of its growth is tested intellectually. The pedagogical approaches cluster only has very strong links to the equity cluster; the emerging technologies cluster has very weak links with the teacher development cluster. The implication of this fragmentation is that scholars in one cluster may be recreating theoretical frameworks that already exist in an adjacent cluster and they have no knowledge of what scholarship has already been created in a neighboring cluster.

The implications for the practices are enormous. By relying on literature in STEM education, policymakers run the risk of getting conflicting advice, as research communities have developed relatively consistent but conceptually incompatible frameworks, in relative isolation of each other. You need to have purposely interdisciplinary collaborative teams relying on cognitive science, sociology, policy studies and educational technology as well as providing depth domain knowledge in STEM education. Synthesizing structures generated by Honey et al. (2014) and Kelley and Knowles (2016) are examples of synthesizing structures used to organize a scholarly field in this manner.

Relative to earlier bibliometric reviews, the present findings both confirm and extend prior work: consistent with Li et al. (2020), integrated STEM and teacher professional development remain dominant themes, but the present full-corpus, network-based approach additionally surfaces the equity and emerging-technologies clusters as increasingly central and traces their historical emergence across four chronological phases in a way that narrower, journal-restricted reviews such as Li et al. (2020) and Roehrig et al. (2021) could not.

## Limitations

This study considers many things, though it has a number of significant limitations that the reader should consider when interpreting the findings.

To begin with, the search is limited to a single database – Scopus. Cross-database verification of WoS revealed that around 21.6 percent of WoS-indexed records of STEM educational research are non-covariant from Scopus, an isomorphism that is non-trivial and thus a coverage bias. A further multi-database analysis factor in the WoS, ERIC and regional databases would have provided a more comprehensive overview of the sector.

Second, the limited scope to English-language publications intentionally narrows the scholarly contributions of non-Anglophone research communities identified in the geographic analysis. Relatedly, the underrepresentation of Global South scholarship identified in the geographic analysis (see discussion) has direct implications for the limitations of this review: thematic clusters, keyword usage, and citation-impact rankings reported here should be read as describing a predominantly Global North research conversation, and may not capture STEM education challenges, priorities, or innovations that are under-published, or published in outlets not indexed by Scopus (e.g., regional or non-English journals common in parts of Africa, South Asia, and Latin America).

Third, co-occurrence network analysis represents author key word labeling behavior, and may not adequately reflected developments described using variable or inconsistent terms. The same construct may be denoted by various terms in different authors, and development of terms across a field can result in seeming gaps in thematic mapping.

Fourth, despite the justification of the key word threshold parameters (minimum occurrence = 5, minimum co-occurrence = 3) based on the recommendations of van Eck and Waltman (2014) and confirmed through a sensitivity analysis (see Method section), the resulting network clusters only 451 of 22,018 unique keyword terms (2.05%). Certain methodologically pertinent terms that are below five times in the corpus, might thus have been left out.

Fifth, publications since 2023 have yet to accrue citations and thus might be underestimating the effect of more recent additions to the corpus. The results pertaining to phase 4 themes (generative AI, computational thinking) may be viewed as tentative.

Sixth, the current study failed to perform co-authorship network analysis (should map collaboration structures across researchers and institutions), or co-citation analysis at level of journal or document (should identify the intellectual base and knowledge fronts of the field). These reviews are a fruitful extension of future bibliometric studies in STEM education should focus on.

Seventh, the institutional-level (university and research center) and funding-body review of the study was not conducted that restricted the ability of the study to follow the intellectual path of the field.

Eighth phases of boundary between structural breaks and theoretically relevant marks (2006-2009, 2010-2014, 2015-2018, and 2019-2026). The phase boundaries (between structural breaks and theoretically relevant marks) were determined through a combination of structural break detection and theoretical markers. Although this dual-justification strategy makes the periodization stronger, alternative location of boundaries would be possible, and readers should remember that the phase characterizations are necessarily interpretive.

Ninth, the reported h-index values of leading authors are their overall career Scopus h-index values do not impact metrics associated with STEM-education. Bibliometric analyses in the future may make use of field-normalized citation indicators or restrict the computation of h-index to publications that relate to the area of STEM education.

Tenth, despite the inclusion/exclusion criteria a clear differentiation of full conference papers in indexed proceedings (included) and standalone conference abstracts (excluded), it is based on Scopus document-type metadata, which is not necessarily uniform across all indexed conference series. A little mis-classification is thus possible, and should be treated as an approximation, given that Scopus document-type metadata is not uniformly standardized across all indexed conference series.

Eleventh, the boundaries of law zone vary with corpus size, composition and must be interpreted with suitable precision. The Bradford multiplier (k = approximately 3.8) and zone boundaries provided here are particular to the current corpus and may change once the field continues to expand.

Twelfth, as with all Scopus-based indicators, the citation counts and indexing patterns reported here are shaped by database-specific indexing policies and journal-inclusion criteria, meaning that some legitimate STEM education scholarship — particularly from regional, non-English, or newly indexed journals — may be systematically undercounted or absent; citation counts themselves index visibility and uptake rather than research quality, and the bibliometric methods used here cannot substitute for qualitative peer assessment of a study's methodological rigor or substantive contribution.

Thirteenth, the resolution of all embedded figures was checked directly: **Figure 1**, **Figure 2**, **Figure 3**, **Figure 6**, and **Figure 7** are embedded at approximately 220-330 dpi at their printed size, which meets standard journal print-legibility thresholds, while **Figure 4** is embedded at approximately 160 dpi, somewhat below the 300 dpi commonly recommended for print; the authors will re-export **Figure 4** from its original VOSviewer/bibliometrix session at higher resolution before final typesetting, and readers accessing a print version in the meantime are encouraged to consult the online supplementary files for the original, zoomable figures.

## CONCLUSION

This two-decade (2006-April 2026) systematic bibliometric research of 7,569 indexed articles including a subset of scholarly publications in STEM education have produced a few high-impact scholarly, policy, and practice implications. There are five overall findings.

To begin with, STEM education has been experiencing growth at an exponential rate: the output of publications has increased more than 20-fold during the study period (from 41 documents in 2006 to 843 in 2025), with CAGR estimates based on endpoint-to-endpoint and regression-based CAGR of 17.2% and 11.4%, respectively, both of which both significantly exceed the general rate of academic publishing. This is attesting to the fact that STEM education ceased being a fringe issue and that it became a significant educational research area.

Second, this growth has been matched by institutionalization which manifests in field-based research communities, dedicated journals, and canon texts that structure the discourse about the field.

Third, a six-cluster network architecture with high score of modularity (Q = 0.74) between research groups is indicated by a co-occurrence network analysis of keywords, which is thematically rich with a worrying intellectual insularity between research groups. The cross-cluster citation analysis confirms the fact that such a level of separation of keywords is reflected in the real bibliographic separation.

Fourth, geographical gaps in the production of knowledge are still deep: the Global South was structurally under-represented in a way that limits the representativeness and generalizability of the available knowledge claims to other geographic regions. A fifth notable finding—that the field is approaching a phase of technological disruption, which will require undertaking fundamental redrawing of theoretical frameworks and professional pedagogies is plausible to make.

To the researcher, the study provides a rich empirical ground upon which scoping literature searches are conducted, in which potentially fruitful research areas (at least at thematic cluster junctions) are identified, and the historical dynamics of the subject is sought. When it comes to policymakers, the identified macro-level patterns can serve as warnings that the particular study or the national context might be not representative of the way STEM education is provided in the world. The findings have implications for journal editors and funding agencies as they demonstrate that, in order to effectively expand the horizons of the field, it is important to actively pursue geographic diversity, promote the cross-cluster interdisciplinary synthesis, and set methodological standards of the computational and AI-integrated STEM education that is rapidly now becoming the new frontier of the field**.** For teacher education programs specifically, the prominence and stability of the curriculum and teacher development cluster across all four chronological phases underscores the continued need for dedicated STEM-specific pre-service and in-service preparation; curriculum developers may likewise use the cluster-level thematic map presented here to identify where integrated-STEM materials are well developed (e.g., pedagogical approaches) versus comparatively underdeveloped (e.g., equity-explicit curricular resources).

Incorporating a variety of databases (WoS and ERIC) would strengthen future bibliometric research by reducing the biases of databases on particular fields of interest, conducting co-authorship and co-citation network analyses to map out collaborative structure and intellectual base, and using longitudinal temporal network analysis to trace how cluster relationships change over time. The longitudinal study of the emerging clusters and, more specifically, the ones focused on generative AI and structural equity will be of particular interest to the researchers whose aim is to anticipate the development of the different fields rather than to simply document the development.

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**AI statement:** The authors did use AI based tools only while preparing this manuscript for language editing and grammar checking. All of the scientific content and the interpretations, conclusions of data are the responsibility of the authors.

**Declaration of interest:** No conflict of interest is declared by the authors.

**Data sharing statement:** Data supporting the findings and conclusions are available upon request from the corresponding author.

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