



## Emerging Trends and Research Directions of STEAM Integration in Mathematics Education

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### Abstract

This study examines the trends of STEAM (Science, Technology, Engineering, Arts, and Mathematics) research in mathematics education from 2020 to February 2026. Guided by PRISMA 2020 procedures, a systematic review of 37 peer-reviewed journal articles was conducted to map temporal growth, geographical distribution, educational levels, methodological orientations, reported outcomes, and research gaps. Findings indicate a marked acceleration of publications after 2021, culminating in a peak in 2025, suggesting consolidation of STEAM as a legitimate research domain in mathematics education. Research production is geographically concentrated, with Indonesia and Spain emerging as dominant contributors, while broader Global South representation remains limited. Methodologically, the field is characterized by a predominance of systematic literature reviews, quasi-experimental studies, and design-based research, reflecting a dual movement toward theoretical consolidation and intervention validation. Reported outcomes primarily emphasize teacher professionalism, pedagogical capacity, 21st-century competencies, positive mathematical dispositions, and sustainability integration, whereas direct and longitudinal evidence of mathematics-specific achievement and numeracy gains remains comparatively underrepresented. Overall, STEAM in mathematics education is transitioning into a phase of epistemic maturation, marked by diversification into STEAM+X frameworks, technological deepening, and growing concern for mathematical integrity and sustainability.

**Keywords:** STEAM; mathematics education; systematic review; trend; PRISMA.

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## INTRODUCTION

STEAM (Science, Technology, Engineering, Arts, and Mathematics) integration serves as an epistemological bridge that connects mathematical reasoning with scientific inquiry and interdisciplinary problem-solving practices, where mathematics functions not only as a computational tool but also as a foundational language for modelling natural phenomena, interpreting scientific data, and supporting engineering design processes. As a prominent framework in contemporary education, STEAM redefines disciplinary boundaries to meet the demands for creativity, problem-solving, and interdisciplinary competence, particularly by situating mathematical reasoning within authentic design processes, modelling activities, and real-world contexts that promote meaningful conceptual understanding beyond procedural knowledge (Li et al., 2020). Furthermore, STEAM integration repositions mathematics as a central epistemic domain that supports innovation, sustainability awareness, and technological literacy projects (Aguilera & Ortiz-Revilla, 2021). However, despite its increasing adoption, STEAM research in mathematics

education remains theoretically and methodologically heterogeneous, with variations in definitions, implementation models, and evaluation frameworks limiting cumulative knowledge and clarity regarding the competencies developed (Margot & Kettler, 2019; Quigley et al., 2017). Therefore, systematic syntheses are needed to map research trajectories, identify dominant orientations, and uncover underexplored areas, particularly across geographical contexts, educational levels, and methodological traditions, to clarify the epistemic direction of mathematics education research in the twenty-first century (Thibaut et al., 2018). To address this need, this study employs a systematic trend-oriented review guided by the PRISMA 2020 framework to ensure transparency and reproducibility (Page et al., 2021), analyzing STEAM research in mathematics education (2020–2026) across temporal, geographical, educational, and methodological dimensions, as well as learning outcomes and research gaps, to clarify its current orientation and future directions in strengthening interdisciplinary innovation and mathematical rigor.

## METHODS

This study applies a systematic review with a trend-analytic orientation to map the development of STEAM research in mathematics education, focusing not on effectiveness but on structural patterns across time, geography, educational levels, methodologies, and outcomes, aligned with a meta-analytic descriptive approach to trace epistemic shifts; guided by PRISMA 2020, it ensures transparency while examining how methods, themes, and outcomes reflect field consolidation and diversification. The corpus was built from systematic searches in OpenAlex and Google Scholar, cross-verified by metadata, limited to peer-reviewed English-language journal articles (January 2020–February 2026), with 2026 data considered provisional; inclusion required explicit STEAM integration in mathematics education, excluding studies without such a focus or outside the criteria, with the PRISMA flow shown in Figure 1.

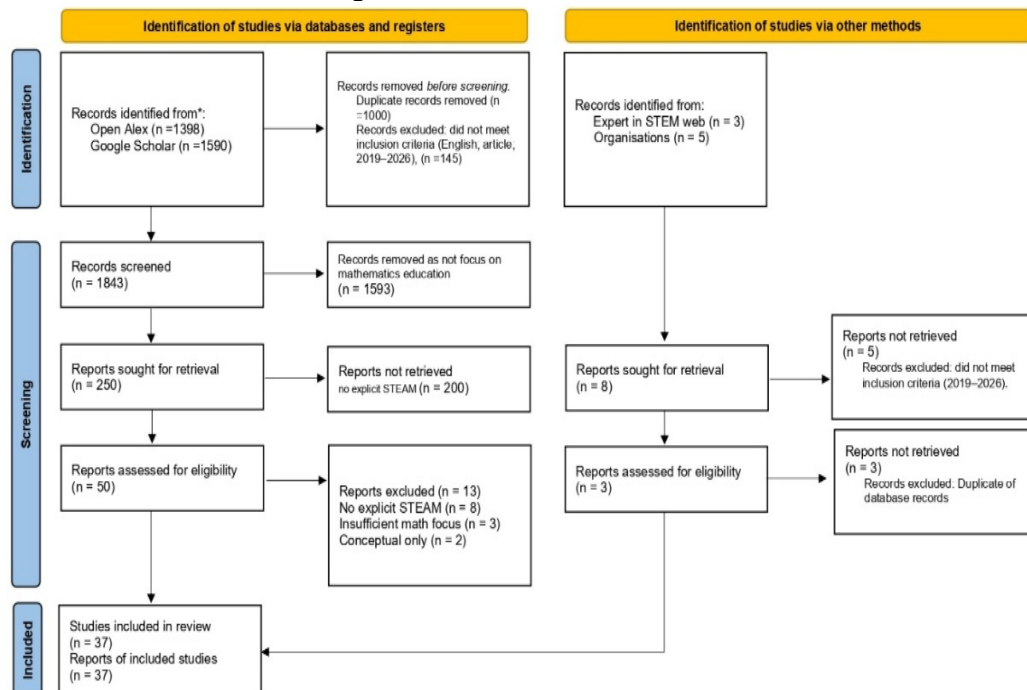


Figure 1. PRISMA Approach of Article Selection Process

### Screening and Selection

The search yielded 2.988 records; after removing 1.000 duplicates and excluding 145 that did not meet criteria, 1.843 records were screened by title and abstract, with 1.593 excluded due to insufficient focus on mathematics education or lack of explicit STEAM integration. Of the 250 reports sought for full text, 200 were inaccessible, leaving 50 assessed for eligibility; 13 were further excluded for lacking STEAM integration ( $n = 8$ ), insufficient mathematical focus ( $n = 3$ ), or purely conceptual nature ( $n = 2$ ), resulting in 37 studies included in the final synthesis. Additionally, eight records from expert consultation and organizational repositories were identified, but five were excluded for not meeting criteria, and three were duplicates, so no additional studies were added beyond the 37 included (<https://bit.ly/SRLSTEAMMATHEDU>), as summarized in Table 1.

Table 1. Overview of Selected Studies Included in the Systematic Review

No	Topic of the articles	Authors
1	Theorizing AI literacy development using Habermas' three cognitive knowledge interests from a systematic review: A STEM interdisciplinary perspective	(Heung et al., 2026)
2	Development of STEAM-based Mathematics Textbook (Primary School)	(Adnan et al., 2023)
3	STEAM Project-Based Approach in Calculus Education	(Breda et al., 2023)
4	STEAM-PjBL for Pre-Service Mathematics Teachers	(Fauziah et al., 2025)
5	An attempt to evaluate STEAM project-based instruction from a school mathematics perspective	(Diego-Mantecon et al., 2021)
6	Integration of STEAM Approach in Mathematics Learning to Enhance Creativity of Elementary School Students	(Sasmita et al., 2025)
7	The Implementation of the STEAM Approach with Indonesia's Local Culture in Mathematics Learning: A Systematic Literature Review	(Kartikaningtyas et al., 2025)
8	Analysis of mathematics education from a STEAM approach at secondary and pre-university educational levels: A systematic review	(Martín-Cudero et al., 2024)
9	STEAM+X Integrated Epistemic Learning Patterns in Ratio Learning for Secondary School Students	(Galang Isnawan et al., 2025)
10	Promoting Mathematics Teacher Education for Sustainability through a STEAM approach	(Alsina & Silva-Hormazábal, 2023)
11	Integrating PjBL-STEAM with Balinese Meru Architecture to Enhance Students' Mathematical Conceptual Understanding	(Putri et al., 2025)
12	Mapping the Evolution of STEAM Education: A Bibliometric Analysis of Global Trends	(Nurazmi et al., 2025)
13	Trends in STEM/STEAM Education and Students' Perceptions in Japan	(Matsuura & Nakamura, 2021)
14	The Impact of a STEAM-Based Intervention on Mathematics Achievement and Gender Differences	(Julius Cheny, 2025)
15	Integrating STEAM Principles in E-Book Design for Game Development Learning: A Systematic Literature Review	(Miccela et al., 2025)
16	Brazilian and Spanish Mathematics Teachers' Predispositions towards Gamification in STEAM Education	(López et al., 2021)
17	Challenges in STEAM Education in Cape Verde: A Mathematics Teacher Training Project	(Dos Santos et al., 2025)
18	Students' Views on STEAM-Based Mathematics Learning	(Aisyah et al., 2024)
19	Integrating STEAM via Virtual Reality: A TPACK-Focused Training Model for Pre-Service Secondary Mathematics Teachers	(Rodríguez & García López, 2026)

No	Topic of the articles	Authors
20	Mathematical numeracy skills for pre-service teacher: An effectiveness of the STEAM framework	(Ibrahim et al., 2026)
21	STEAM+X in Mathematics Education: A Systematic Literature Review	(Isnawan et al., 2025)
22	STEAM education: Student learning and transferable skills. <i>Journal of Research in Innovative Teaching &amp; Learning</i>	Bertrand et.al (2021)
23	The Challenges of STEAM Education: What is Expected of a Bibliometric Approach to the Training of Mathematics Teachers?	(Vera & Arroyo, 2025)
24	From the Steam Engine to STEAM Education: An Experience with Pre-Service Mathematics Teachers	(Herrero et al., 2023)
25	The Effectiveness of Mathematics Learning with the STEAM Approach in Improving Students' Critical Thinking Skills	(Ichsan, 2024)
26	Students' Mathematical Reflective Thinking Ability on Statistics Material with STEAM Approach	(Machromah & Musthofa, 2023)
27	Promoting Pre-service Teachers' Professionalism in STEAM Education and ESD through Mathematical Modelling	(Wiegand & Borromeo Ferri, 2023)
28	Exploring the Determinants of Mathematics Teachers' Willingness to Implement STEAM Education	(Tang et al., 2025)
29	Examining the Implementation of Environmental Education in the STEAM Approach for Sustainability	(Djam'an, 2025)
30	STEAM Camp: Teaching Middle School Students Mathematics, Science and Coding through Digital Designs	(Bertrand et al., 2023)
31	Challenging Examples of the Wise Use of Computer Tools for the Sustainability of Knowledge and Developing Active and Innovative Methods in STEAM and Mathematics Education	(Körtési et al., 2022)
32	Sustainable Development of STEAM and Mathematics Education with Active and Innovative Methodology	(Jeong & González-Gómez, 2024)
33	Social Sustainability of the Teaching Profession: Pedagogical Beliefs and Pre-Service Teachers' Digital Competence in STEAM	(Şahin, 2026)
34	Outdoor STEAM integrated framework in elementary schools in Luxembourg using MathCityMap and GeoGebra 3D Calculator	Ben Haas et.al (2020)
35	A Study on the Impact of STEAM Education for Sustainable Development Courses and Its Effects on Student Motivation and Learning	(Hsiao & Su, 2021)
36	Designing a STEAM-Infused Project-Based Learning Framework to Foster Mathematics Students' Critical and Creative Thinking	(Ikhlas et al., 2025)
37	The Use of STEAM in Mathematics Education: A Systematic Literature Review	(Asmara Dewi et al., 2025)

The review is limited to English-language journal publications and excludes conference proceedings and grey literature. No formal quality appraisal scoring was conducted, as the primary aim was to identify macro-level structural tendencies rather than evaluate intervention effectiveness. Accordingly, the findings should be interpreted as indicative of research directionality and epistemic development within the STEAM mathematics domain, rather than as definitive claims about pedagogical impact.

## RESULTS & DISCUSSION

The synthesis of 37 studies shows a clear expansion of STEAM research in mathematics education since 2020, accelerating after 2021 and shifting from procedural instruction toward interdisciplinary, contextual, and project-based approaches aligned with 21st-century competencies and ESD. Key trends include the dominance of STEAM-PjBL (especially in secondary, higher, and teacher education), increased use of digital

technologies (e.g., GeoGebra, coding, VR/AR) to support visualization and modelling, and the growth of culturally grounded approaches integrating ethnomathematics and sustainability. Overall, STEAM is evolving toward greater epistemic refinement, technological integration, and socio-cultural responsiveness.

## Results

### Distribution of Publications by Year

The year-by-year distribution shows a transition from sporadic early output (e.g., 2020: 2.7%) to accelerated consolidation in the mid-2020s, with a peak in 2025 (37.9%), indicating a shift toward STEAM as a mainstream research focus driven by growing emphasis on interdisciplinary competence, digital transformation, and sustainability-oriented reforms. The presence of 2026 publications (10.8%) suggests sustained momentum, although still provisional due to indexing up to February 2026, while earlier fluctuations (e.g., 2022 and 2024) reflect responsiveness to funding cycles, post-pandemic curricular shifts, and evolving research priorities, overall indicating a field gaining legitimacy and coherence despite ongoing developmental transition (see Figure 2).

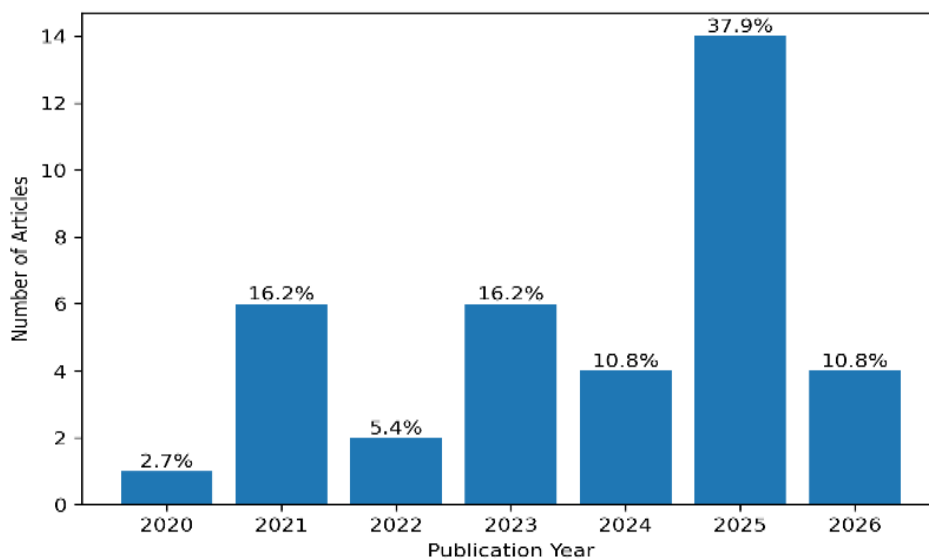


Figure 2. Distribution of Articles by Publication Year

### Geographical Distribution

The geographical landscape shows both expansion and concentration, with Indonesia as the dominant contributor (38%), followed by Spain (14%), suggesting that national curriculum reforms and institutional agendas strongly influence research production. Other countries, such as Portugal, Germany, and China, contribute in smaller proportions (1–5%), resulting in a long-tail distribution where scholarship remains clustered rather than evenly spread; this spatial pattern is illustrated in Figure 3.

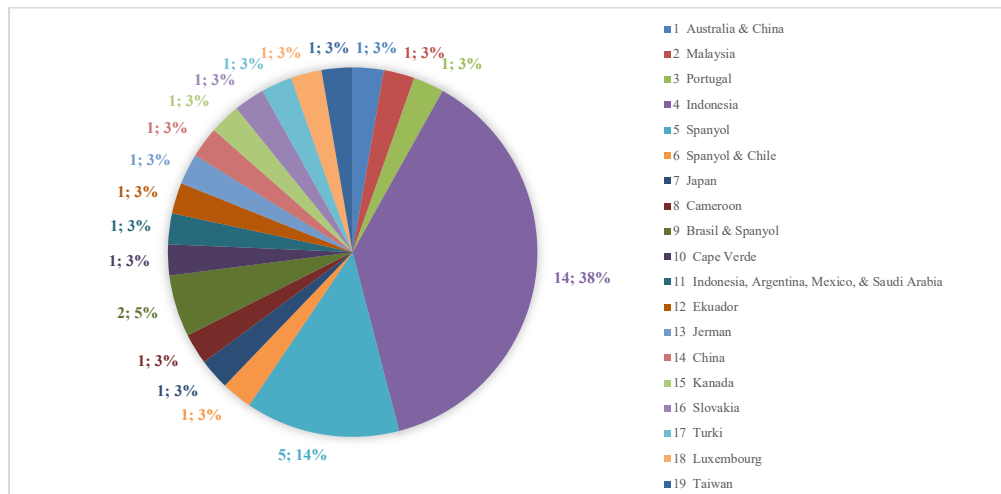


Figure 3. Geographical Distribution of the STEAM Mathematics Education Studies

Importantly, several studies involve cross-national collaboration, suggesting that STEAM mathematics education research is increasingly embedded in international academic networks. While this indicates gradual epistemic diversification, the strong concentration in specific countries also implies that theoretical framing and empirical priorities may still be disproportionately influenced by regional agendas. Thus, although transnational engagement is expanding, geographical imbalance persists.

**Distribution by Educational Level**

Research activity is uneven across educational levels, with secondary education dominating (27.02%, n = 10), followed by higher education (21.63%, n = 8), indicating a strong focus on interdisciplinary integration, modelling, and higher-order thinking within competency-based contexts (see Figure 4). Studies on in-service teachers (16.22%, n = 6) highlight the need for professional capacity building, while elementary-level research (13.51%, n = 5) remains limited and largely focused on instructional development or perceptions; a similar proportion spans multiple levels but is mainly conceptual or review-based. Pre-service teacher research is minimal (8.11%, n = 3), revealing a gap in preparation for STEAM pedagogy. Overall, this reflects a dual trajectory of strong empirical work at secondary and tertiary levels alongside growing theoretical consolidation, with limited attention to early education and pre-service training potentially constraining long-term sustainability.

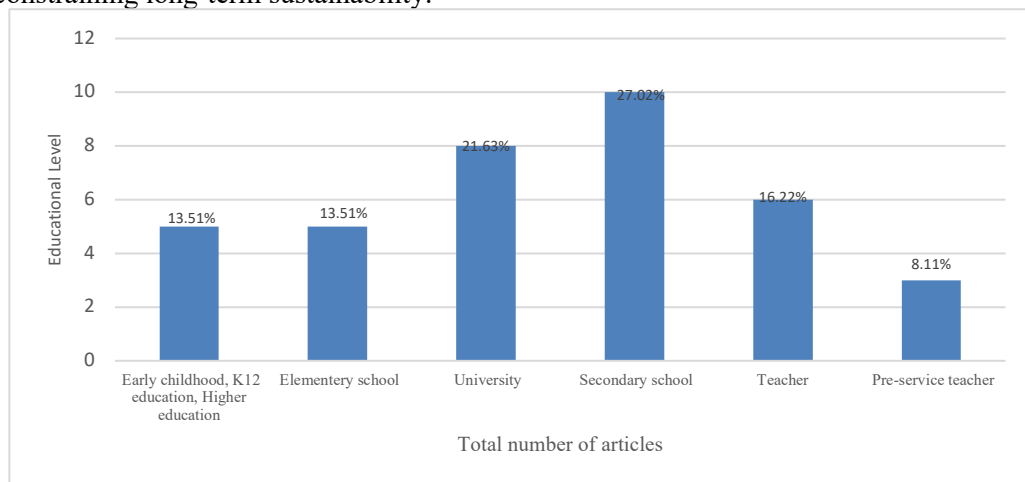


Figure 4. Distribution of Educational Level

### Methodological Distribution

The distribution indicates a field undergoing consolidation and intervention-driven expansion. Systematic Literature Reviews constitute the largest proportion (29.73%), signaling efforts to synthesize prior findings and stabilize conceptual foundations. Quasi-experimental designs (27.03%) and Design-Based Research (21.62%) dominate empirical approaches, reflecting a strong orientation toward testing and refining STEAM interventions within authentic classroom settings. The methodological profile of the corpus is presented in Figure 5.

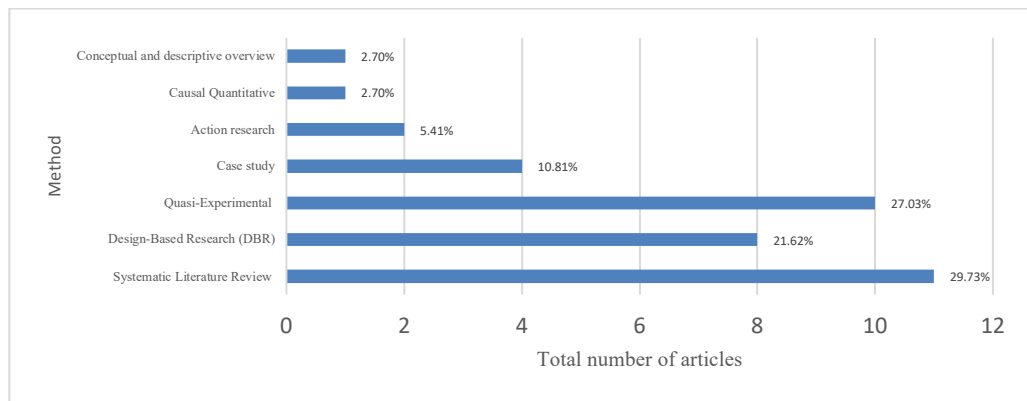


Figure 5. Distribution of Research Methods

In contrast, case studies (10.81%) and action research (5.41%) play a more limited role, suggesting that contextualized practitioner inquiry remains secondary to effectiveness-oriented designs. Causal quantitative modeling and purely conceptual studies (each 2.70%) are comparatively rare, indicating that large-scale explanatory modeling and advanced theoretical development remain underexplored. Overall, the methodological landscape reflects a transition from exploratory innovation toward structured validation and synthesis.

### Distribution of Reported Outcomes

The outcome profile shows that STEAM research in mathematics education prioritizes pedagogical transformation and professional capacity over direct measures of achievement, with teacher professionalism (19%), attitudes toward mathematics, and 21st-century skills (each 16.2%) dominating, indicating a focus on capacity building and affective development (see Figure 6). In contrast, mathematics achievement and numeracy (each 2.7%) are rarely emphasized, while greater attention is given to engagement, conceptual understanding, cultural relevance, sustainability, and instructional development, reflecting a shift toward STEAM+ESD and context-responsive approaches; overall, this suggests a field in transitional maturation that emphasizes innovation and broader competencies but lacks strong longitudinal and controlled evidence of mathematics-specific gains.

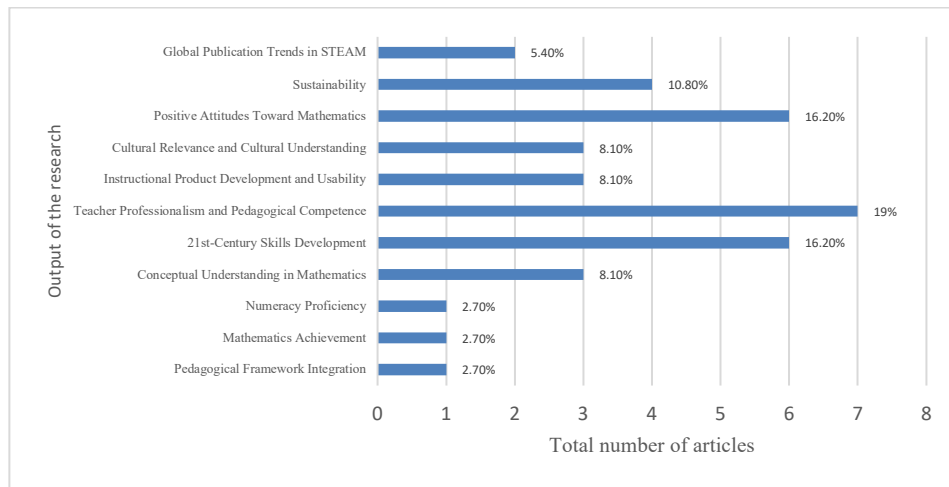


Figure 6. Distribution of Research Outputs

### Research Gaps

Despite the rapid expansion of STEAM research in mathematics education, the field remains unevenly consolidated, with evidence largely dominated by short-term, small-scale, quasi-experimental studies and limited longitudinal or controlled designs to establish sustained causal impacts on mathematics-specific achievement; outcomes often emphasize engagement, creativity, and 21st-century competencies, while direct measures such as conceptual depth, numeracy progression, and standardized achievement are underrepresented, and geographical concentration alongside limited cross-national studies restricts generalizability. Structurally, tensions persist regarding the epistemic role of mathematics within STEAM, as it is not consistently positioned as the conceptual core, highlighting the need for clearer learning trajectories, consistent assessment tools, and theoretically grounded frameworks; moreover, research on pre-service teacher preparation, scalable professional development, and sustainable curriculum integration remains limited, particularly in non-European and Global South contexts, underscoring the need for greater experimental rigor, longitudinal designs, cross-context replication, and deeper conceptual clarity to advance STEAM toward robust and evidence-based practice.

### Discussion

Journal publications, conferences, seminars, and workshops serve as key dissemination channels in mathematics education, and to enhance comprehensiveness and reduce database bias, this review complemented database searches with expert web and manual searches of institutional and personal repositories of STEAM scholars, following systematic review recommendations (Petticrew & Roberts, 2005), with all additional records screened under PRISMA 2020 to ensure transparency and rigor (Page et al., 2021). The findings indicate that STEAM research increasingly emphasizes conceptual understanding, modelling, numeracy, and higher-order thinking, aligning with the view that complex competencies arise from integrating multiple literacies (Heung et al., 2026), while the shift toward STEAM+X, integrating culture, sustainability (ESD/SDGs), and digital technologies reflects broader digitalization and sustainability agendas; in Indonesia, this aligns with technology-integrated learning (Seldry et al., 2025) and the Kurikulum Merdeka, positioning STEAM as a bridge linking mathematical reasoning with real-world

and sustainability challenges within global competence-based education (Kemdikbudristek, 2022; Perignat & Katz-Buonincontro, 2019; UNESCO, 2020).

The synthesis shows that STEAM research in mathematics education has entered a consolidation phase marked by increased publication, thematic diversification, and methodological sophistication, with the post-2021 surge reflecting an epistemic shift from exploratory work toward analytically grounded studies positioning mathematics as a central domain, alongside growing integration into tertiary curricula and teacher education supported by teacher capacity development and digital learning (Djam'an et al., 2023). However, long-term progress requires alignment with policy frameworks (Clarke, 2019), as the field continues transitioning toward epistemic consolidation where interdisciplinary innovation intersects with mathematical legitimacy, sustainability, and systemic change; despite gains in engagement and competencies, sustainable transformation depends on coherence among pedagogy, teacher development, and curriculum reform (Boaler, 2022; English, 2016). Thus, STEAM should be viewed as a systemic paradigm linking mathematics with societal and sustainability challenges, with future research emphasizing longitudinal and controlled studies, mathematically grounded designs, and scalable, equitable professional development to ensure sustained rigor and alignment across research, practice, and policy (OECD, 2023; Thomas & Watters, 2015).

This study systematically uncovers structural patterns, methodological tendencies, and persistent conceptual gaps that explain why mathematics-related learning outcomes remain underrepresented within STEAM implementations. By mapping these relationships across educational levels, geographical contexts, and research designs, the findings advance existing knowledge by clarifying how mathematics can function as a modelling and analytical foundation supporting scientific literacy and evidence-based reasoning within Mathematics and Natural Sciences Education learning ecosystems. This integrative perspective contributes novel insight into the alignment between interdisciplinary innovation and disciplinary rigor, offering research-informed directions for curriculum integration, assessment development, and sustainable STEM science learning practices. Consequently, the study extends current STEAM scholarship by providing an analytical basis for strengthening conceptual integration across mathematics and natural sciences education, thereby supporting future Mathematics and Natural Sciences Education - oriented educational transformation (National Academy of Engineering and National Research Council, 2014).

## CONCLUSION

This systematic trend analysis shows that STEAM research in mathematics education has evolved from exploratory interdisciplinary work to a more consolidated and analytically grounded field between 2020 and early 2026, marked by increased publications, methodological maturation, and growing emphasis on teacher professionalism, 21st-century skills, sustainability, and STEAM+X integration. The review provides a comprehensive synthesis of trends, methods, and gaps, offering valuable guidance for researchers, educators, and policymakers while clarifying the field's conceptual development. Although quasi-experimental and design-based studies effectively enhance engagement, creativity, and problem-solving, evidence on mathematics achievement and numeracy remains inconsistent, highlighting the need for more rigorous, longitudinal, and controlled research. Despite progress, structural gaps persist, including limited mathematics-specific outcomes, underrepresentation of large-scale and cross-national studies, and geographical concentration, indicating that future research must

strengthen methodological rigor, mathematical grounding, scalability, and contextual diversity to ensure sustainable, equitable, and impactful mathematics education reform.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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