Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram
https://e-journal.undikma.ac.id/index.php/prismasains/index
e-mail: prismasains.pkpsm@gmail.com

July 2026. Vol. 14, No. 3
p-ISSN: 2338-4530
e-ISSN: 2540-7899
_pp. 1258–1274_

Global Trends of STEAM Research in Science Education (2010–2025): A Bibliometric Review

[a*]Dedi Prasojo, [a]Syamsu, [a]Sudarsono, [b]Supriyatman, [c]Afadil, [d]Rafiqa
[a]Doctoral Program in Science Education, Postgraduate School; [b]Science Education Study Program; [c]Chemistry Education Study Program; [d]Biology Education Study Program, Faculty of Teacher Training and Education; Universitas Tadulako. Jl. Soekarno Hatta KM 9 Tondo, Mantikulore, Palu, Indonesia

*Corresponding Author e-mail: dediprasojo7@gmail.com

Received: December 2025; Revised: June 2026; Published: July 2026

Abstract

Science education has experienced a substantial paradigm shift over the last decade, driven by the demands of the twenty-first century, rapid technological advancement, and the need for innovative, multidisciplinary approaches to learning. This study aims to examine global research trends in STEAM (Science, Technology, Engineering, Arts, and Mathematics) within the context of science education from 2010 to 2025 using a bibliometric approach. Data were retrieved from the Scopus database and analyzed using Biblioshiny, VOSviewer, and Microsoft Excel to map publication growth, citation patterns, collaboration networks, and thematic development. A total of 114 Scopus-indexed journal articles were identified and analyzed following a rigorous screening process based on predefined inclusion and exclusion criteria. The results indicate a substantial increase in STEAM-related publications, particularly after 2018, reflecting growing global interest in interdisciplinary and creativity-oriented science education. The United States emerged as the most productive and influential country, with strong international collaboration networks. Keyword and thematic analyses reveal that "science education," "STEAM," and "engineering education" function as motor themes, while "STEM," "curriculum," and "creativity" serve as foundational themes. Emerging topics such as computational thinking and computer science education highlight the increasing integration of digital competencies in STEAM pedagogy. Overall, the findings demonstrate that STEAM research in science education has evolved into a dynamic and interdisciplinary field, providing valuable insights for researchers, educators, and policymakers in shaping future research directions and educational practices.

Keywords: STEAM education; science education; bibliometric analysis; Scopus; Biblioshiny; research trends

How to Cite: Prasojo, D., Syamsu, S., Sudarsono, S., Supriyatman, S., Afadil, A., & Rafiqa, R. (2026). Global Trends of STEAM Research in Science Education (2010–2025): A Bibliometric Review. *Prisma Sains : Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, *14*(3), 1258–1274. https://doi.org/10.33394/j-ps.v14i3.18812

https://doi.org/10.33394/j-ps.v14i3.18812

INTRODUCTION

Science education has undergone a substantial paradigm shift over the past decade, driven by twenty-first-century competencies, rapid technological advancement, and increasing demands for interdisciplinary and innovation-oriented learning (Sucilestari et al., 2025). Within this transformation, STEAM (Science, Technology, Engineering, Arts, and Mathematics) education has emerged as a prominent framework that extends traditional STEM by explicitly integrating creativity, artistic practices, and design-based thinking into science learning contexts (Dewi et al., 2022; Hong & Song, 2020; Setiawan et al., 2023). In contrast to general STEAM education discourses that often emphasize broad curricular integration, STEAM within the science education boundary places science concepts, scientific inquiry, and disciplinary epistemologies as the core learning foundation, with technology, engineering, arts, and mathematics functioning as integrative and supportive dimensions. This boundary is critical, as it reflects a distinct pedagogical orientation that prioritizes conceptual understanding, scientific practices, and evidence-based reasoning while fostering creativity, collaboration, and problem-solving skills (Markula & Aksela, 2022; Tsybulsky & Muchnik-Rozanov, 2021).

As policymakers and educators worldwide seek to prepare learners for complex socio-scientific and industrial challenges, STEAM has increasingly been positioned as a strategic approach in science education to promote holistic learning, innovation capacity, and student engagement across diverse educational levels and contexts (Shin et al., 2021). Correspondingly, a growing body of research has examined STEAM from multiple perspectives, including pedagogical models, curriculum design, technology integration, teacher readiness, and learning outcomes (Yustina et al., 2020). These studies span early childhood to higher education and report both positive impacts such as enhanced creativity, motivation, and conceptual understanding and persistent challenges, including limited teacher professional development, fragmented instructional frameworks, and uneven institutional support (Setianingrum et al., 2023; Suryaningsih, 2023; Tran, 2021). The rapid expansion of digital technologies, including virtual laboratories, robotics, artificial intelligence, and creative media platforms, has further diversified STEAM research themes within science education (Fatonah et al., 2023; Kareem, 2022). Despite this expansion, existing reviews of STEAM education remain largely thematic or narrative, often focusing on specific educational levels, pedagogical models, or regional contexts, resulting in fragmented insights into the field’s overall development (Asyari et al., 2024). Comprehensive, longitudinal analyses that systematically map the thematic evolution, intellectual foundations, and collaborative structures of STEAM research specifically within science education are still limited. This gap highlights the need for a robust bibliometric mapping approach capable of revealing macro-level research trends, knowledge structures, and emerging directions across time (Maričić & Lavicza, 2024; Martínez et al., 2024; Spyropoulou & Kameas, 2024).

The scientific novelty of this study does not reside merely in the application of bibliometric techniques, which have become increasingly common in STEAM-related scholarship, but in its systematic and theory-informed mapping of STEAM research specifically within the science education domain over a 15-year period using Scopus-indexed publications. Unlike traditional literature reviews that rely on subjective synthesis and limited sampling, this study employs bibliometric analysis to quantitatively examine longitudinal publication dynamics, thematic evolution, and structural relationships among research topics, authors, institutions, and countries, thereby revealing macro-level patterns that are not readily visible through narrative approaches (Aghasafari et al., 2025). More specifically, this study advances existing bibliometric work by integrating multiple analytical layers, including publication trend analysis, co-authorship and international collaboration networks, thematic clustering, and citation-based intellectual structure mapping. The use of Biblioshiny strengthens this contribution by enabling systematic visualization of thematic evolution across defined time phases, co-citation networks that expose the intellectual foundations of the field, and emerging research fronts, thus providing a comprehensive and data-driven representation of how STEAM research in science education has developed and diversified over time (Arango-Caro et al., 2025). Furthermore, this study addresses a critical gap in the literature by offering a long-term, global-scale perspective that explicitly situates STEAM within the science education boundary. Previous reviews and bibliometric analyses have either focused on general STEAM education or examined limited timeframes and regional contexts, resulting in fragmented or partial understandings of the field’s development (Asyari et al., 2024; Martínez et al., 2024).

Several research problems persist within the existing literature on STEAM in science education. First, despite the rapid growth of publications, the global evolution of STEAM research remains insufficiently understood, particularly regarding regional dominance, shifts in research productivity over time, and the rise or decline of specific thematic foci. Without a longitudinal and comparative perspective, it is difficult to determine whether observed trends reflect sustained scholarly development or temporary research interests. Second, the structural relationships among authors, institutions, and countries involved in STEAM research have not been comprehensively examined. The absence of systematic mapping of co-authorship and institutional collaboration networks limits understanding of how knowledge is produced, disseminated, and internationally connected within the field, as well as which actors play central or bridging roles in shaping research directions. Third, although recent studies suggest the emergence of new focal areas, there is a lack of empirical, large-scale evidence identifying and contextualizing emerging themes that may define the future of STEAM research in science education. Topics such as artificial intelligence–supported learning, sustainability-oriented STEAM frameworks, and innovative assessment models are frequently mentioned, yet their relative prominence, developmental trajectories, and interconnections within the broader research landscape remain unclear.

Therefore, the purpose of this article is to conduct a comprehensive bibliometric analysis of global STEAM research in science education using Scopus and Biblioshiny, with the aim of mapping publication trends, thematic developments, intellectual structures, and potential research opportunities from 2010 to 2025. This review seeks to contribute novel insights to the field by presenting an evidence-based understanding of the evolution and current position of STEAM within the global scientific community.

METHOD

This study employed a comprehensive bibliometric mapping methodology to analyze global research trends in STEAM (Science, Technology, Engineering, Arts, and Mathematics) within the field of science education from 2010 to 2025. The primary source of data for this analysis was the SCOPUS database, recognized as one of the largest and most authoritative abstract and citation indexing platforms for peer-reviewed scientific literature. All STEAM-related publications were retrieved directly from the SCOPUS interface using a structured search strategy, with outputs exported in CSV and RIS formats for compatibility with Biblioshiny and other bibliometric tools. The exported data fields included document titles, authors, abstracts, author keywords, affiliations, citation counts, source titles, and publication years.

To ensure methodological rigor, the data extraction and cleaning procedures followed established bibliometric protocols and were reviewed by domain experts prior to analysis. This ensured consistency, reduced the risk of data omission, and enhanced accuracy in identifying trends, collaboration networks, and thematic developments in STEAM research. SCOPUS was selected as the exclusive data source due to its extensive international coverage, stringent journal indexing standards, and its widespread use in global bibliometric and scientometric studies, thereby ensuring the comprehensiveness, reliability, and scholarly validity of the dataset. Additionally, Biblioshiny an R-based web interface for Bibliometrix was employed to generate visualizations of publication growth, co-authorship networks, thematic evolution, and keyword co-occurrence patterns. This approach enabled a detailed and data-driven mapping of the intellectual landscape of STEAM research within science education over the 15-year period.

Sample Preparation

To ensure analytical rigor and relevance, a multi-stage filtering process was implemented using predefined inclusion and exclusion criteria, as detailed in Table 1. These criteria were designed to align with best practices in bibliometric research and enhance reproducibility.

Table 1. Inclusion and exclusion criteria

Category	Inclusion	Exclusion

Article Type	Scientific articles on ICT assessment in mathematics learning, published in indexed journals (not proceedings) and open access.	Articles not using quantitative, qualitative, or mixed methods.
Time Frame	Studies published between 2010 and 2025.	Studies published before 2010.
Sample	Students at secondary and undergraduate education levels.	Students notat secondary or undergraduate levels.
Language	Articles in English or Indonesian.	Articles in languages other than English or Indonesian.
Research Focus	Studies evaluating the use of ICT in mathematics assessment, including computer-based testing platforms, digital applications, electronic portfolios, or specialized mathematics assessment software.	Studies that do not focus on the use of ICT or digital tools in mathematics learning assessment.

This formulation ensured a comprehensive capture of relevant literature. The terms were refined iteratively and validated by three independent experts in science education and bibliometric methods to verify coverage breadth and thematic relevance. A total of 229 case study documents related to STEAM and science education were initially identified from the Scopus database. After applying preliminary data filtering, 219 studies remained for further assessment. Subsequent screening based on eligibility criteria resulted in 116 studies. Of these, 10 studies were excluded based on predefined parameter settings, and an additional 2 studies were removed following a detailed eligibility review. Consequently, a total of 114 studies were deemed suitable and included in the bibliometric analysis. This exclusion breakdown is clearly aligned with the narrative in Figure 1.

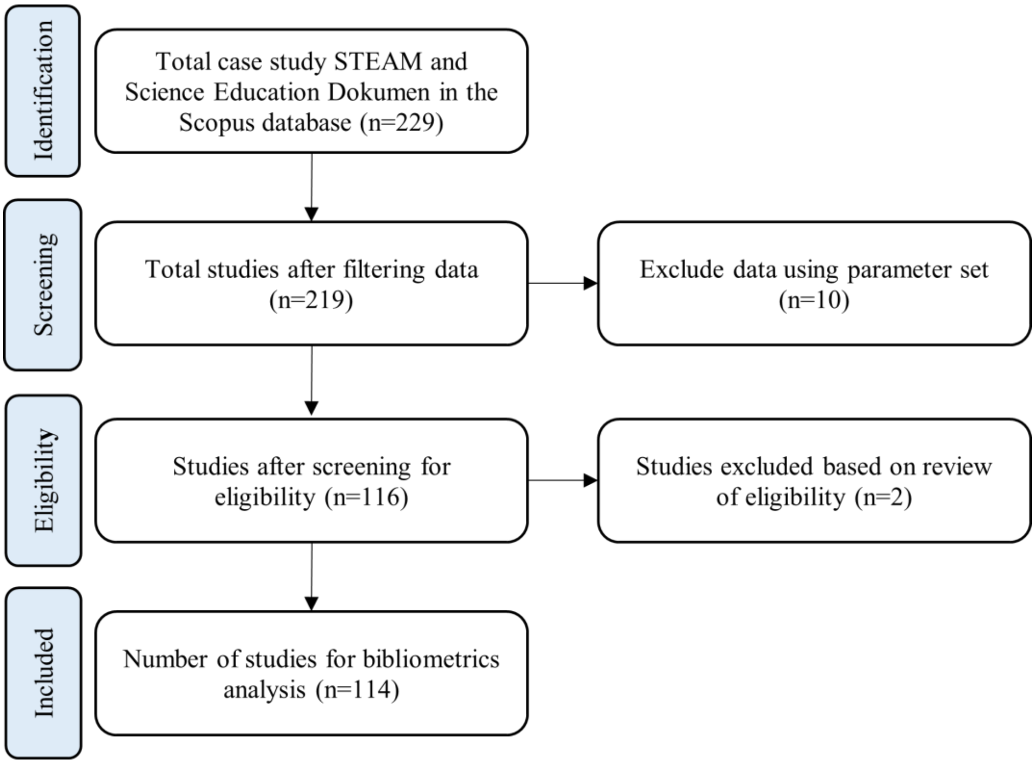

Figure 1. The PRISMA flow diagram detailing the screening and selection process of literature

Experimental Set-Up

The analytical workflow for this study was designed to systematically capture global trends in STEAM research within the field of science education and to ensure the reproducibility of all bibliometric procedures (Markula & Aksela, 2022; Tsybulsky & Muchnik-Rozanov, 2021). A combination of widely recognized bibliometric tools: Microsoft Excel, VOSviewer, and Biblioshiny (the web interface of the *bibliometrix* R package) was employed to maximize the extraction of meaningful patterns from the Scopus dataset covering the period 2010–2025.

Microsoft Excel was first utilized for the organization and preliminary cleaning of the raw data exported from Scopus, including the removal of duplicates, standardization of author names and affiliations, and initial descriptive statistics such as annual publication frequencies and document-type distributions. This preparatory stage ensured that the dataset was consistent and properly structured for advanced bibliometric analysis. VOSviewer (Martínez et al., 2024) was then employed to construct and visualize bibliometric networks central to mapping STEAM research dynamics in science education. Its robust capability to handle large datasets enabled the generation of high-resolution visualizations for co-authorship networks, keyword co-occurrence networks, citation networks, and bibliographic coupling. These network structures provided valuable insights into collaboration patterns, influential authors, dominant research themes, and the intellectual connections shaping the development of STEAM scholarship worldwide.

Biblioshiny, built on the bibliometrix R-package, was used to conduct more advanced analyses, including thematic evolution, trend topic modeling, scientific production by country, authorship impact, and source title productivity (Asyari et al., 2024; Martínez et al., 2024). Its interactive interface allowed for the generation of thematic maps and temporal analyses, enabling the identification of emerging and declining themes within STEAM research in science education across the 15-year period. The overall methodological sequence consisted of data importation, rigorous data cleaning (e.g., normalization of keywords, authors, and institutional names), descriptive bibliometric analysis, and network-based mapping. Key bibliometric indicators including publication counts, citation patterns, collaboration rates, source productivity, and keyword evolution were systematically extracted to reveal the global landscape and developmental trajectory of STEAM-related scholarship. All analytical steps were documented in detail to ensure methodological transparency, allowing future researchers to replicate and extend the findings in subsequent bibliometric investigations.

Parameters

Several bibliometric parameters and indicators were measured to characterize the research landscape of STEAM education. The core parameters included:

- Publication Output: Annual and cumulative number of articles published, revealing growth trends and shifts in scholarly attention.
- Source Analysis: Distribution of articles by source title, identification of leading journals, and cumulative occurrences over time.
- Authorship and Collaboration: Analysis of author productivity, international collaboration (single-country vs. multiple-country publications), author affiliations, and geographical distribution of contributions.
- Citation Analysis: Identification of highly cited articles, influential authors, and countries, enabling the assessment of research impact and visibility.
- Keyword Analysis: Extraction and co-occurrence mapping of author keywords to identify core research topics, thematic clusters, and evolving trends in literature.
- Thematic and Trend Analysis: Thematic mapping, trend topic visualization, and evolution analysis to reveal the intellectual structure and development of the STEAM education field.

Statistical Analysis

Quantitative and network-based bibliometric analyses were conducted to ensure the generation of robust, valid, and reproducible findings throughout the study (Rosa et al., 2020). Descriptive statistics including frequency distributions, percentage calculations, and annual growth rates were initially produced using Microsoft Excel to provide an overview of publication behavior and temporal trends within the STEAM science education domain. This descriptive layer offered foundational insights into the yearly evolution of research productivity, document types, and citation patterns. For deeper structural analysis, advanced statistical mapping and network-based techniques such as co-occurrence, co-authorship, and bibliographic coupling were implemented using VOSviewer, which is widely recognized for its capacity to visualize large-scale bibliometric networks with high clarity and computational efficiency (Roth et al., 2022). These network analyses played a crucial role in identifying intellectual linkages among authors, mapping collaborative structures, and detecting clusters of frequently co-occurring concepts within STEAM-related scholarship.

The bibliometrix R-package was further employed to conduct conceptual structure analysis, thematic evolution mapping, and trend topic modeling, drawing upon methodological frameworks extensively validated in previous comparative science-mapping research (Shin et al., 2021). Through these analytical procedures, the study was able to examine the development of conceptual themes over time, identify core research domains, and detect emerging or declining topics shaping the trajectory of STEAM research in science education. All visual outputs generated across software platforms were systematically reviewed to ensure interpretive coherence, conceptual validity, and alignment with well-established bibliometric standards (Setiawan et al., 2023). Additionally, normalization techniques including fractional counting and the harmonization of author or institutional variants were applied where appropriate to address potential biases arising from multi-authored publications or inconsistent metadata. To maintain data integrity, every analytical step underwent iterative cross-validation, ensuring accuracy and reducing the possibility of methodological error.

The integration of descriptive statistics with advanced network-based bibliometric techniques enabled a holistic and multidimensional mapping of the global STEAM education research landscape (Fatonah et al., 2023). This combined approach made it possible to capture both macro-level patterns such as publication growth and geographic distribution and micro-level structures, including research clusters, conceptual linkages, and collaboration networks. Employing multiple validated software tools and adhering strictly to established bibliometric protocols significantly enhanced the rigor, transparency, and replicability of the methodological framework. This is fully consistent with emerging standards and methodological advancements in contemporary bibliometric science-mapping studies (Kareem, 2022). Overall, this robust analytic strategy ensured that the study produced comprehensive, evidence-based insights into the global development of STEAM research within science education from 2010 to 2025.

RESULTS AND DISCUSSION

General Information

Table 2 presents the main bibliometric characteristics of highly cited STEAM education research indexed in the Scopus database during the 2010–2025 period. A total of 114 documents were analyzed, originating from 76 sources, including journals and other scholarly outlets. The dataset shows a relatively high annual growth rate of publications (23.6%), indicating a rapid expansion of research interest in STEAM education over the analyzed timeframe. The average age of the documents is 3.03 years, suggesting that the field is dominated by relatively recent publications, while the average number of citations per document reaches 14.69, reflecting a strong scholarly impact. Overall, the analyzed studies cited a total of 1,038 references, underscoring the theoretical and empirical richness of STEAM education research.

Table 2. Highly cited STEAM education research

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2010:2025
Sources (Journals, Books, etc)	76
Documents	114
Annual Growth Rate %	23.6
Document Average Age	3.03
Average citations per doc	14.69
References	1038
DOCUMENT CONTENTS	
Keywords Plus (ID)	212
Author's Keywords (DE)	377
AUTHORS	
Authors	504
Authors of single-authored docs	0
AUTHORS COLLABORATION	
Single-authored docs	0
Co-Authors per Doc	7.39
International co-authorships %	27.19
DOCUMENT TYPES	
Article	114

In terms of content characteristics, the documents include 212 Keywords Plus and 377 author-provided keywords, demonstrating a broad thematic diversity and interdisciplinary orientation. Authorship analysis reveals the involvement of 504 authors, with no single-authored documents identified, highlighting the collaborative nature of research in this field. This trend is further supported by an average of 7.39 co-authors per document and an international co-authorship rate of 27.19%, indicating substantial cross-country research collaboration. Regarding document types, all analyzed publications are journal articles (n = 114), confirming that peer-reviewed articles constitute the primary medium for disseminating influential STEAM education research.

Table 2 highlights the most highly cited articles in STEAM education published during the analyzed period, reflecting foundational and influential contributions to the field. The most cited study, *"Exploring Teachers' Perceptions of STEAM Teaching Through Professional Development: Implications for Teacher Educators"* by Herro and Quigley, underscores the pivotal role of teacher professional development in effectively implementing STEAM pedagogy and fostering interdisciplinary teaching practices. Other highly cited works further enrich the field by addressing key dimensions of STEAM education, including the implementation of STEAM approaches in middle school contexts, the significance of creativity, autonomy, and student engagement in learning processes (Thuneberg et al., 2018), as well as assessment strategies designed to evaluate collaboration and teamwork within STEAM-based learning activities (Aghasafari et al., 2025). Collectively, these influential studies illustrate the multifaceted nature of STEAM education research, encompassing pedagogical design, learner-centered approaches, and evaluative frameworks that support effective interdisciplinary instruction.

The recurrent appearance of authors such as Herro, Quigley, and Bogner across multiple highly cited publications highlights their sustained and influential contributions to the conceptual development, empirical grounding, and methodological advancement of STEAM education research. Their works have played a critical role in shaping key pedagogical frameworks, instructional strategies, and assessment models that continue to inform subsequent studies in the field. Furthermore, the inclusion of more recent research addressing digital technologies and artificial intelligence (AI) (Tsybulsky & Muchnik-Rozanov, 2021) demonstrates the field's adaptive capacity and responsiveness to rapid technological innovation and evolving educational demands in the digital era. Collectively, the observed annual publication trends and citation patterns indicate not only a growing scholarly impact but also an increasing thematic diversification of STEAM education research, thereby underscoring its significance as a dynamic, interdisciplinary, and strategically important domain within contemporary education studies (Markula & Aksela, 2022).

Publication Trends of STEAM in Science Education

A bibliometric analysis of 114 Scopus-indexed publications reveals a significant increase in research on STEAM education from 2010 to 2025. During the early period (2010–2014), publication output was relatively low and predominantly consisted of conceptual studies that emphasized the distinctions between STEM and STEAM. From 2015 to 2018, there was a marked rise in the number of articles examining the implementation of STEAM within science education contexts, particularly at the secondary and higher education levels (Fatonah et al., 2023).

The upward trend in publications after 2018 has been driven by several global factors, including creativity-oriented education policies, the widespread adoption of digital technologies, and increasing demands for the development of 21st-century competencies (Asyari et al., 2024; Martínez et al., 2024). The publication trend graph (Figure 2) illustrates a sharp increase beginning in 2020, coinciding with the expansion of online learning in the post COVID-19 pandemic period, during which STEAM approaches were increasingly adapted for digital, project-based, and collaborative learning environments (Shin et al., 2021). This trend indicates that STEAM research in science education has evolved from primarily conceptual discourse toward the implementation of innovative pedagogical practices. Accordingly, it can be concluded that STEAM education now occupies a central role in global science education reform, particularly in integrating scientific knowledge and creativity to enhance students' scientific literacy and innovative capacity (Asyari et al., 2024).

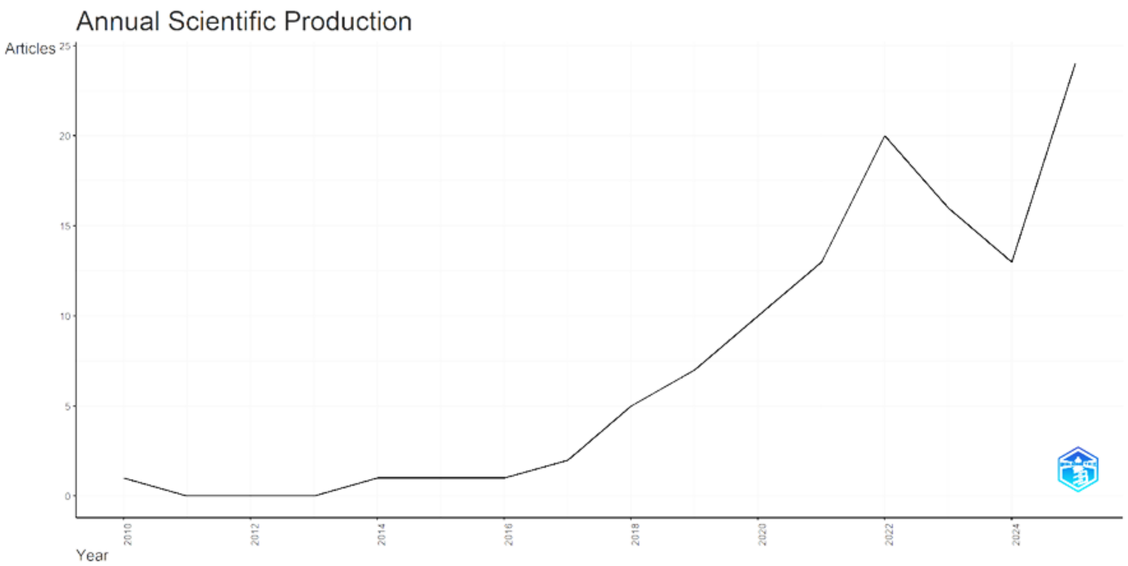

Figure 2. Publication trends of STEAM in science education

Most Influential Authors

Figure 3 illustrates authors' production over time, showing the temporal distribution of publications by individual authors across different years. The size of the bubbles represents the number of articles published, while the color intensity indicates total citations per year. The figure reveals that several authors began contributing around 2016–2018, with a noticeable increase in publication activity after 2020. Some authors show consistent productivity across multiple years, while others exhibit peak outputs in specific periods, particularly between 2021 and 2023. Overall, Figure 3 highlights the growing research productivity and impact of key authors over time, with recent years demonstrating higher publication intensity and citation influence.

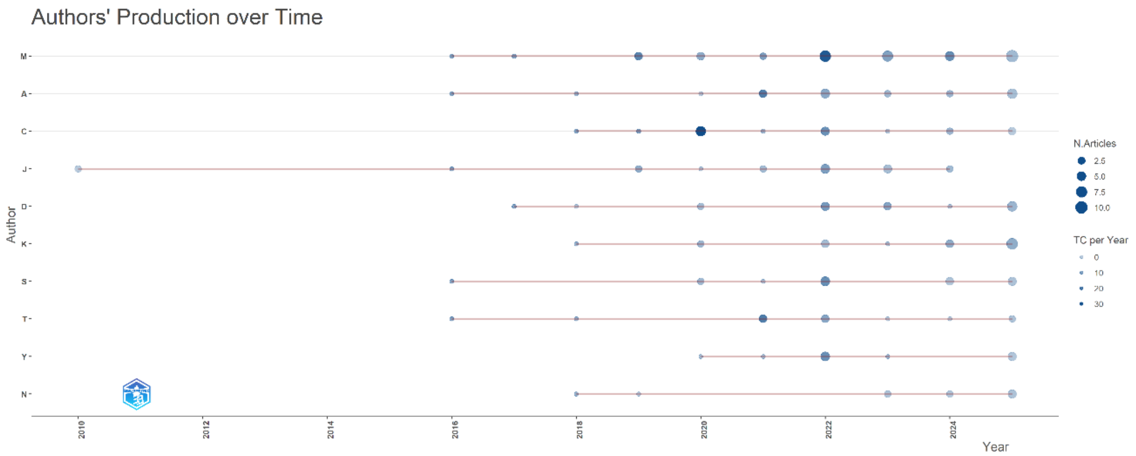

Figure 3. Authors' production over time

In summary, the field of STEAM education is largely shaped by a core group of highly productive and influential authors who consistently contribute to the literature and play a pivotal role in defining research directions and scholarly discourse. Many of these authors are affiliated with well-established and reputable institutions across North America, Europe, and Asia, which serve as important centers for knowledge production and academic collaboration. Their sustained scholarly output, reflected in continuous publication activity over time, combined with extensive national and international collaboration networks, facilitates the dissemination of innovative pedagogical frameworks, empirical findings, and theoretical advancements. Collectively, these contributions are instrumental in advancing research, informing educational policy, and strengthening evidence-based practice in STEAM education, thereby reinforcing its development and impact on a global scale (Yustina et al., 2020).

Most Influential Country

Figure 4 illustrates the distribution of corresponding authors' countries in STEAM education research by differentiating between single-country publications (SCP) and multiple-country publications (MCP), thereby providing insights into national research productivity and international collaboration patterns. The United States clearly dominates the field, contributing the highest number of publications overall. Its strong presence in both SCP and MCP indicates not only a robust domestic research capacity but also an active engagement in international research collaborations, positioning the USA as a central hub in the global STEAM education research network.

Spain and China emerge as the next most productive countries. Spain demonstrates a relatively balanced pattern between SCP and MCP, suggesting that its STEAM education research is supported by both national efforts and cross-border collaborations. In contrast, China's publication output is predominantly composed of single-country publications, reflecting a research landscape that is largely driven by domestic institutions and nationally oriented research agendas. Meanwhile, countries such as Germany, Turkey, and the United Kingdom show moderate publication outputs with noticeable levels of international collaboration, indicating their roles as active contributors within regional and global research networks. Overall, Figure 4 highlights significant disparities in both productivity and collaboration among countries. While a small number of countries particularly the United States play a leading role in shaping the global discourse on STEAM education, other countries contribute through more specialized or regionally focused research efforts. These patterns underscore the importance of international collaboration in enhancing the visibility, impact, and cross-cultural relevance of STEAM education research worldwide (Syaipul et al., 2025).

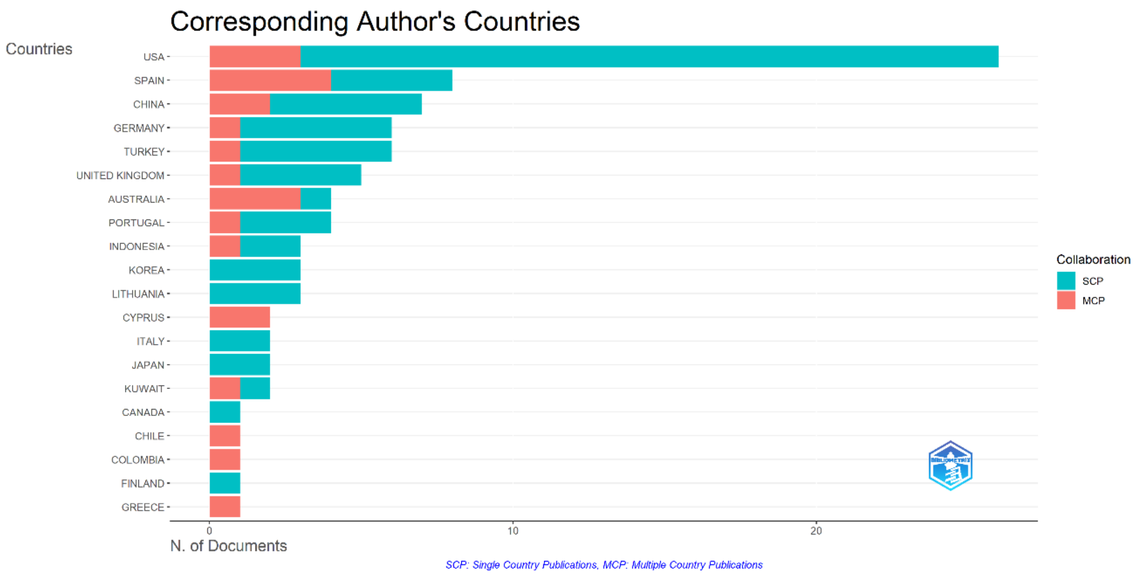

Figure 4. Corresponding author's countries: Geographical collaboration: single-country and multiple-country publications

Most Relevant Keywords

Figure 5 illustrates a tree map of authors' keywords employed in STEAM education research published between 2016 and 2025, offering a comprehensive overview of the thematic structure and research priorities within the field. The visualization reveals that "science education" and "STEAM" are the most frequently occurring keywords, each accounting for 50 occurrences (15%), underscoring the central role of scientific disciplines and integrative STEAM approaches in shaping contemporary educational discourse. This dominance suggests that STEAM education research remains strongly anchored in science-based learning while simultaneously promoting interdisciplinary integration.

Following these core themes, "STEAM education" (18; 5%) and "engineering education" (12; 4%) emerge as key focus areas, reflecting increasing scholarly attention to formal pedagogical models and engineering-based problem-solving within STEAM contexts. The presence of "STEM" and "STEM education" as recurring keywords further indicates the conceptual continuity and overlap between STEM and STEAM paradigms, highlighting ongoing discussions regarding disciplinary integration and the inclusion of arts in science and technology education. Additionally, frequently used keywords such as "students", "learning", "mathematics education", "computational thinking", "curriculum", and "teaching" point to a strong pedagogical orientation in the literature. These terms emphasize learner-centered approaches, instructional strategies, and curriculum development as central components of STEAM education research. Keywords related to creativity, art education, and integration also signal the importance of holistic learning experiences that foster innovation and interdisciplinary thinking.

Meanwhile, the appearance of less frequent but emerging keywords such as "virtual reality", "project-based learning", "scientific inquiry", "integration", and "educational technology" suggests a growing interest in technology-enhanced learning environments and experiential pedagogies. Although niche keywords such as "adult education", "informal learning", "COVID-19", and "collaboration" appear with lower frequencies, their inclusion reflects the diversification of research topics and contexts within the STEAM education field. Overall, the tree map demonstrates that STEAM education research encompasses a broad and evolving thematic landscape, combining well-established foundational concepts with emerging and innovative topics. This balance highlights the dynamic nature of the field and its responsiveness to educational, technological, and societal developments, thereby shaping the ongoing global discourse on STEAM education (Dewi et al., 2022; Hong & Song, 2020; Setiawan et al., 2023).

Figure 5. Tree map of authors' keywords

Figure 6 illustrates a thematic map of keyword co-occurrence in STEAM education research, organized along two dimensions: relevance degree (centrality) on the horizontal axis and development degree (density) on the vertical axis. The visualization shows that "science education" occupies a central and dominant position in the network, indicating its pivotal role in structuring STEAM education research. Its strong connections with keywords such as "STEAM education," "STEM education," and "creativity" suggest that science education serves as a core conceptual bridge linking interdisciplinary integration and innovative pedagogical approaches. The prominence of these connections reflects the centrality of science learning contexts in operationalizing STEAM principles within educational research.

Another major cluster is centered on "STEAM," which is closely associated with "STEM," "project-based learning," and creativity-oriented approaches. This cluster highlights the pedagogical emphasis on integrative learning models that combine multiple disciplines through authentic, hands-on, and project-based instructional strategies. The strong linkage between STEAM and STEM indicates that STEAM education continues to evolve from its STEM foundation while incorporating artistic and creative dimensions to enhance student engagement and problem-solving skills (Yeomans et al., 2025).

In addition, a distinct cluster related to digital and computational perspectives is visible, connecting "computational thinking" with "computer science education." Although this cluster is positioned somewhat peripheral to the central science education node, the visible connections indicate that computational thinking has become an increasingly important component of STEAM education research. This trend reflects the growing recognition of computational skills as essential competencies for learners in interdisciplinary and technology-rich learning environments (Shin et al., 2021). Overall, Figure 6 reveals that STEAM education research is characterized by a highly interconnected and interdisciplinary thematic structure, with science education functioning as the central anchor. The coexistence of pedagogical themes (such as project-based learning and creativity), disciplinary foundations (STEM and science education), and emerging digital competencies (computational thinking and computer science education) demonstrates the multidimensional nature of the field. This network structure suggests that current STEAM education scholarship balances the consolidation of core educational concepts with the integration of innovative instructional approaches and digital skills, thereby shaping the ongoing development and future directions of STEAM education research.

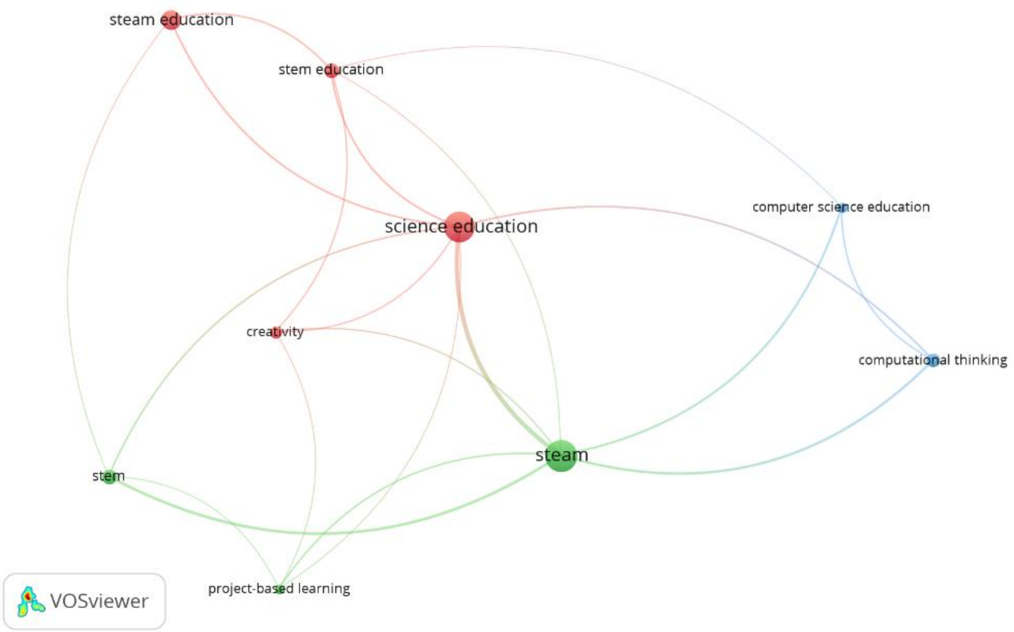

Figure 6. Keywords co-occurrence analysis by network visualization

Current Research Landscape in STEAM Education

Figure 7 illustrates the temporal evolution of key research topics in STEAM education from 2019 to 2025, highlighting shifts in scholarly attention across different themes over time. The analysis reveals that “science education,” “STEAM,” and “STEAM education” represent the most prominent and enduring topics within the field. These terms show relatively high frequencies, particularly during the period from 2021 to 2023, indicating that integrated science-based approaches and STEAM-oriented pedagogical frameworks have become central pillars of contemporary research.

In addition to these core themes, topics such as “engineering education,” “mathematics education,” and “learning” demonstrate sustained visibility across multiple years. Their continued presence suggests a strong emphasis on interdisciplinary content integration and learner-centered instructional strategies within STEAM education. The appearance of “computational thinking” around 2021 further reflects the growing importance of digital literacy, problem-solving skills, and algorithmic thinking as essential components of modern STEAM curricula (Tran, 2021).

Earlier trend topics, including “curriculum,” “creativity,” and “computer science education,” are more prominent around 2019–2020, indicating that initial research efforts focused on curricular design and creative skill development as foundational elements of STEAM implementation. Meanwhile, more recent topics such as “science technologies” and "middle school" emerge toward the later years of the analysis period, suggesting an increasing research interest in technology-enhanced learning environments and targeted educational contexts. Overall, Figure 7 demonstrates that STEAM education research has evolved from an early emphasis on curriculum and creativity toward a stronger focus on interdisciplinary science education, computational competencies, and technology integration. This progression reflects the field's responsiveness to technological advancements and educational demands, highlighting a dynamic and continuously evolving research landscape.

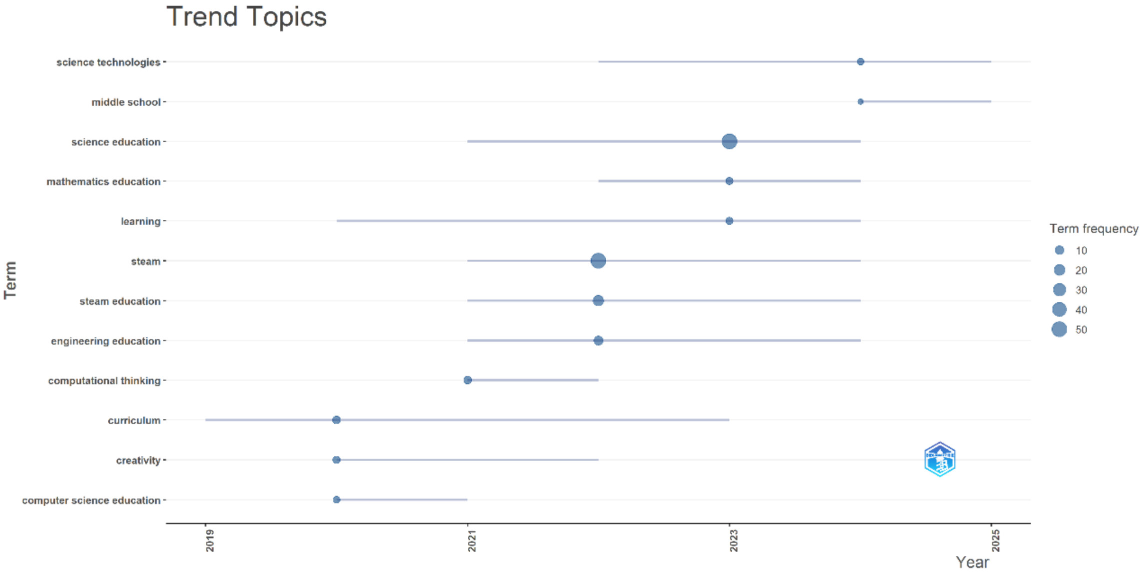

Figure 7. Trend topics of STEAM education

Figure 8 presents a thematic map that classifies research themes in STEAM education according to their degree of relevance (centrality) on the horizontal axis and their level of development (density) on the vertical axis. This mapping enables a clearer understanding of which themes function as driving forces in the field, which serve as foundational concepts, and which represent either specialized or emerging areas of inquiry. The upper-right quadrant, representing motor themes, contains highly central and well-developed topics that play a key role in structuring STEAM education research. Prominent among these are "science education," "STEAM," and "engineering education," indicating that these themes are not only theoretically mature but also deeply embedded in the core discourse of the field. In addition, themes such as "learning," "human," "article," "computational thinking," and "computer science education" are also positioned within this quadrant, highlighting the growing importance of learner-centered perspectives and computational competencies. Their presence suggests that contemporary STEAM research increasingly emphasizes cognitive processes, human factors, and digital skills as integral components of interdisciplinary education (Yeomans et al., 2025).

The lower-right quadrant, which represents basic themes, includes "STEM," "curriculum," and "creativity." These themes exhibit high centrality but relatively lower density, indicating that they are fundamental and widely referenced across studies, yet not as deeply or cohesively developed as motor themes. Their positioning suggests that while these concepts form the conceptual backbone of STEAM education, there remains significant potential for further theoretical consolidation and empirical elaboration, particularly in curriculum design and creativity-focused pedagogical models. Meanwhile, the upper-left quadrant contains niche themes, such as "science–arts collaboration" and "science classroom." These topics demonstrate high internal development but low centrality, implying that they represent specialized lines of research that are methodologically mature but less connected to the broader STEAM education discourse. Such themes often reflect focused pedagogical or contextual explorations that, while valuable, remain peripheral to mainstream research trends.

The lower-left quadrant, which identifies emerging or declining themes, includes "scientific inquiry," "science communication," and "SSI" (socio-scientific issues). These themes show both low centrality and low density, suggesting that they are either newly emerging areas that have yet to gain substantial traction or topics whose prominence has diminished over time. Their location points to opportunities for renewed scholarly attention, particularly in linking inquiry-based and communication-oriented approaches with contemporary STEAM frameworks. Overall, Figure 8 reveals a dynamic and evolving thematic structure within STEAM education research. The coexistence of dominant motor themes, foundational basic themes, specialized niche topics, and emerging or declining areas reflects the field's multidimensional nature (Syaipul et al., 2025).

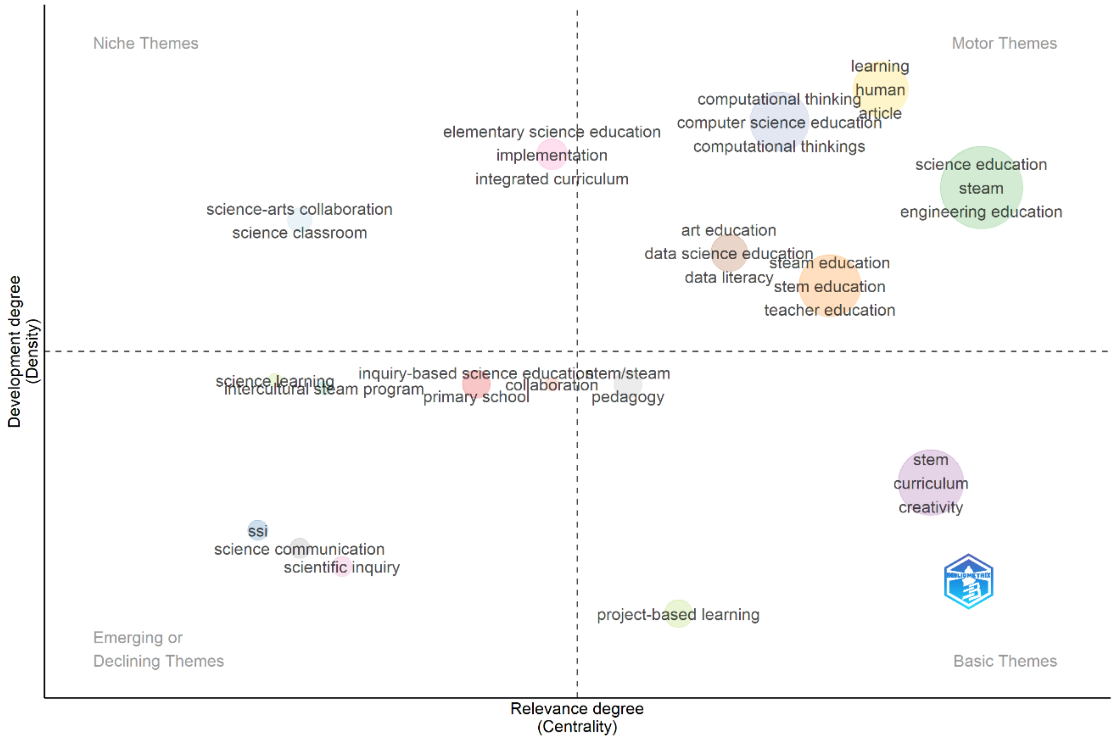

Figure 8. Thematic map of STEAM education

CONCLUSION

This study provides a comprehensive bibliometric overview of global STEAM research in science education from 2010 to 2025. The findings demonstrate a significant and sustained growth in publication output, particularly in the post-2018 period, indicating that STEAM has become a central paradigm in contemporary science education research. The dominance of science education, STEAM, and engineering education as motor themes confirms their critical role in shaping theoretical frameworks and pedagogical practices. Furthermore, the strong presence of themes related to learning, computational thinking, and computer science education reflects a growing emphasis on learner-centered approaches and digital competencies. At the same time, foundational themes such as STEM, curriculum, and creativity continue to underpin the field, although they show potential for deeper theoretical and empirical development. Overall, the bibliometric evidence highlights that STEAM education research is highly collaborative, interdisciplinary, and increasingly responsive to technological and societal demands, positioning it as a key driver of innovation in science education worldwide.

RECOMMENDATION

Based on the findings, several recommendations can be proposed. Future research should focus on strengthening empirical investigations of foundational themes such as curriculum integration and creativity to enhance their theoretical coherence within STEAM frameworks. Greater attention is also needed to emerging themes, including computational thinking, artificial intelligence, and sustainability, to ensure their meaningful integration into science education practice. Researchers are encouraged to expand cross-national and cross-cultural collaborations, particularly involving underrepresented regions, to promote a more balanced global research landscape. Additionally, policymakers and educators should utilize bibliometric insights to inform evidence-based curriculum design, teacher professional development, and educational policy formulation. Finally, future bibliometric studies may consider integrating multiple databases or longitudinal comparative analyses to further enrich the understanding of STEAM education's evolving research trajectory.

Acknowledgments
The authors would like to express their sincere gratitude to Tadulako University for its academic support and institutional facilities that contributed to the completion of this study. The support provided by the Doctoral Program in Science Education, Postgraduate School, Universitas Tadulako, played an important role in facilitating this research. The authors also acknowledge the supportive academic environment that enabled the successful conduct and dissemination of this bibliometric study.

Funding Information
This research did not receive external funding.

Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Dedi Prasojo	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	
Syamsu		✓				✓		✓	✓	✓	✓	✓		
Sudarsopo	✓		✓	✓			✓			✓	✓		✓	✓
Supriyatman					✓		✓			✓		✓		✓
Afadil			✓	✓			✓			✓	✓		✓	✓
Rafiqa		✓				✓		✓	✓	✓	✓	✓		

Conflict of Interest Statement
Authors state no conflict of interest

REFERENCES

Aghasafari, S., Needles, T., & Malloy, M. (2025). Multimedia arts learning: connecting STEAM among special education students. *Discover Education*, 4(1). https://doi.org/10.1007/s44217-025-00440-7

Arango-Caro, S., Langewisch, T., Ying, K., Haberberger, M. A., Ly, N., Branton, C., & Callis-Duehl, K. (2025). 3D plants: the impact of integrating science, design, and technology on high school student learning and interests in STEAM subjects and careers. *Disciplinary and Interdisciplinary Science Education Research*, 7(1), 1–18. https://doi.org/10.1186/s43031-025-00120-4

Asyari, A., Meiliyadi, L. A. D., Sucilestari, R., & Arizona, K. (2024). Exploring Student Creativity and Collaboration Through Project-Based Learning With Google Sites. *Jurnal Pendidikan Islam*, 10(2), 308–322. https://doi.org/10.15575/jpi.v10i2.40215

Chung, C. C., Lin, C. L., & Lou, S. J. (2018). Analysis of the learning effectiveness of the STEAM-6E special course-a case study about the creative design of IoT assistant devices for the elderly. *Sustainability (Switzerland),* 10(9), 1–16. https://doi.org/10.3390/su10093040

Dewi, R. K., Kholis, N., Marpuah, S., Ghozali, M., & Syahrudin, S. (2022). ICT Based Chemistry Learning Innovation To Improve Student's Creativity In The Digital Era. *Journal of Social Transformation and Regional Development*, 4(2), 65–74. https://doi.org/10.30880/jstard.2022.04.02.008

Fatonah, S., Prasetyo, Z. K., Utami, A. D., Chasanah, U., Lusiana, L., & Siregar, V. V. (2023). Scientific Attitude and Its Effect on Students' Productivity. *Jurnal Pendidikan IPA Indonesia*,12(4), 658–671. https://doi.org/10.15294/jpii.v12i4.47727

Hong, O., & Song, J. (2020). A componential model of Science Classroom Creativity (SCC) for understanding collective creativity in the science classroom. *Thinking Skills and Creativity*, 37, 100698. https://doi.org/10.1016/j.tsc.2020.100698

Kareem, A. (2022). Higher-Order Thinking Skills and Scientific Attitudes Components as Predictors of Scientific Creativity Among Preservice Biology Teachers. *International Journal of Progressive Education*, 18(4), 21–30. https://doi.org/10.29329/ijpe.2022.459.2

Maričić, M., & Lavicza, Z. (2024). Enhancing student engagement through emerging technology integration in STEAM learning environments. *Education and Information Technologies*, 29(17), 23361–23389. https://doi.org/10.1007/s10639-024-12710-2

Markula, A., & Aksela, M. (2022). The key characteristics of project-based learning: how teachers implement projects in K-12 science education. *Disciplinary and Interdisciplinary Science Education Research*, 4(1). https://doi.org/10.1186/s43031-021-00042-x

Martínez, J., Montés, N., & Zapatera, A. (2024). STEAM Architecture—A STEAM Project for Pre-University Studies to Connect the Curricula with Architectural Concepts. *Education Sciences*, 14(12), 1–19. https://doi.org/10.3390/educsci14121348

Rosa, F. O., Mundilarto, Wilujeng, I., & Mujriah. (2020). The integration of collaborative problem solving with "piil pesenggiri" local wisdom to build scientific attitudes. *Universal Journal of Educational Research*, 8(11), 5246–5256. https://doi.org/10.13189/ujer.2020.081125

Roth, T., Conradty, C., & Bogner, F. X. (2022). Testing Creativity and Personality to Explore Creative Potentials in the Science Classroom. *Research in Science Education*, 52(4), 1293–1312. https://doi.org/10.1007/s11165-021-10005-x

Setianingrum, D. A., Matahari, D. B., Jumadi, J., & Wilujeng, I. (2023). Development of Science e-Book Containing Gamelan's Local Wisdom Based on STEAM-POE to Facilitate Students' Love of Local Culture. *Jurnal Penelitian Pendidikan IPA*, 9(6), 4791–4800. https://doi.org/10.29303/jppipa.v9i6.3760

Setiawan, P., Wahidin, & Arif, A. G. (2023). Application of the Project Based Learning (PjBL) Model through Making Tempe to Improve Student Learning Outcomes and Creativity. *Influence: International Journal of Science Review*, 5(2), 239–249. https://doi.org/10.54783/influencejournal.v5i2.153

Shin, N., Bowers, J., Krajcik, J., & Damelin, D. (2021). Promoting computational thinking through project-based learning. *Disciplinary and Interdisciplinary Science Education Research*, 3(1). https://doi.org/10.1186/s43031-021-00033-y

Shin, N., Bowers, J., Krajcik, J., & Damelin, D. (2021). Promoting computational thinking through project-based learning. *Disciplinary and Interdisciplinary Science Education Research*, 3(1). https://doi.org/10.1186/s43031-021-00033-y

Spyropoulou, N., & Kameas, A. (2024). Leveraging Communities of Practice for STEAM Education: A Study on Engagement and Professional Development. *European Journalof Education*, 59(4), 1–12. https://doi.org/10.1111/ejed.12806

Sucilestari, R., Arizona, K., Mutiara, B., Nirmala, A., & Aspia, A. (2025). Exploring the Effectiveness of Project-Based Blended Learning in Science E-Books for Improving Digital Literacy. *Jurnal Penelitian Pendidikan IPA*, 11(6), 509–518. https://doi.org/10.29303/jppipa.v11i6.11131

Suryaningsih, S. (2023). STEAM digital project: Creating scientific E-poster to develop student's creativity and digital literacy in 21st century. *In AIP Conference Proceedings* (Vol. 2595). https://doi.org/10.1063/5.0123746

Syaipul Hayat, M., Sumarno, Qotrun Nada, N., & Yunus, M. (2025). Integrating physical activity and Edupas-based STEAM-SDGs forstudents' sustainability awareness in vocational education. *Retos*, 64, 520–531. https://doi.org/10.47197/retos.v64.109836

Tran, N. H. (2021). Exploring the Effectiveness of STEAM-Based Courses on Junior High School Students' Scientific Creativity. *Frontiers in Education*, 6. https://doi.org/10.3389/feduc.2021.666792

Tsybulsky, D., & Muchnik-Rozanov, Y. (2021). Project-based learning in science-teacher pedagogical practicum: the role of emotional experiences in building preservice teachers' competencies. *Disciplinary and Interdisciplinary Science Education Research*, 3(1). https://doi.org/10.1186/s43031-021-00037-8

Yeomans, L., Chappell, K., Hetherington, L., Bresciani, S., Unterfrauner, E., Fabian, C. M., & Koulouris, P. (2025). Practice or Praxis? A Theoretical Classification System for STEAM Education. *Education Sciences*, 15(2), 1–24. https://doi.org/10.3390/educsci15020164

Yustina, Syafii, W., & Vebrianto, R. (2020). The effects of blended learning and project-based learning on pre-service biology teachers' creative thinking skills through online learning in the COVID-19 pandemic. *Jurnal Pendidikan IPA Indonesia*, 9(3), 408–420. https://doi.org/10.15294/jpii.v9i3.24706