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STEM and STEAM Education in Secondary School Science: A Systematic Review of Research Trends (2021–2025)

Umi Shalihah Putri Purwati[1], Dwi Siti Nur Hayati[2]

[1,2] Department of Science Education, Universitas Negeri Yogyakarta, Indonesia
*Email: umishalihah.2023@student.uny.ac.id

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ABSTRACT

Purpose – STEM (Science, Technology, Engineering, and Mathematics) and STEAM (Science, Technology, Engineering, Arts, and Mathematics) have been widely adopted as interdisciplinary learning approaches that integrate multiple disciplines to address the challenges of 21st-century education. This study aims to systematically examine research trends in STEM- and STEAM-based science learning at the secondary school level during the period 2021–2025.

Methodology – This study employed a systematic literature review using the PRISMA approach. The article search process was conducted through the ERIC and Scopus databases. This study was limited to articles discussing science learning at the secondary school level. Based on the selection and screening process according to the PRISMA approach, 39 articles were obtained for further analysis.

Findings – Research indicates that STEM topics are more prevalent than STEAM topics in secondary school science subjects. The dominant science material combined with STEM or STEAM is physics. The cognitive domain frequently appears in both STEM and STEAM research. Empirical research is needed to determine the potential of the STEM or STEAM approach to improve learning skills.

Contribution - This research provides a methodological overview of the research patterns that have developed in the STEM and STEAM approach in science learning at the secondary school level in the last five years, so that it can be a reference for future researchers in designing empirical research and further studies

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INTRODUCTION

The world has now entered the 21st century, along with corresponding changes in contemporary learning approaches. In this highly dynamic era, the importance of STEM (Science, Technology, Engineering, and Mathematics) education—or STEAM, which also incorporates the arts—has become increasingly critical. (Fajrina, Lufri, & Ahda, 2020). STEM and STEAM approaches are designed to foster essential 21st-century skills, such as critical thinking, creativity, collaboration, and problem-solving, which are crucial for addressing global challenges and responding to rapid technological advancements (Asrizal, Usmeldi, & Azriyanti, 2023; Astawan et al., 2023; Ilma et al., 2023; Oanh & Dang, 2025). The implementation of STEM across various countries has increasingly emphasized the importance of digital literacy, adaptability, innovation, and the integration of technology into learning as a response to industrial transformation and evolving workforce demands. (Verma, 2024). Therefore, STEM approaches serve as a foundation for shaping a generation that is adaptable, capable of flexible thinking, and well-prepared to compete in an increasingly dynamic and technology-oriented society.

STEM in science education has evolved into approaches that emphasize interdisciplinary integration to support students in developing a holistic understanding of scientific concepts (Maryna et al., 2025; Nugraha, Kidman, & Tan, 2024). Science learning that adopts this approach does not teach concepts in physics, biology, or chemistry in isolation; instead, it integrates them with technology, engineering, and design to address real-world problems (Yang & Baldwin, 2020). Implementation in the classroom may take the form of projects, problem-based experiments, and product design and development (Abdurrahman, Maulina, & Nurulsari, 2023; Afrijal, Yulianti, & Rohman, 2023; Nur & Ikhsan, 2024). Through these activities, students are encouraged to apply scientific concepts in real-world contexts that foster the development of 21st-century skills (Muchtar & Ding, 2024; Pasani & Amelia, 2021). Activities designed within STEM approaches also support deeper and more meaningful conceptual understanding (Arti, Widowati, & Krautharot, 2025).

The implementation of STEM in science education presents various challenges related to classroom instructional processes. These approaches require interdisciplinary integration that connects their constituent components. Variations in school contexts, students' abilities, and differences in infrastructural support also influence the effectiveness of implementation (Bardoe et al., 2023; Tunc & Bagceci, 2021). Such conditions result in highly diverse STEM instructional practices across the field, leading to inconsistent learning outcomes. Furthermore, the integration of engineering, technology, and design elements demands more complex pedagogical competencies, which in some cases have not been fully developed by educators (Yüksel, 2025). This situation produces differing implementation dynamics across studies.

Research on STEM and STEAM in science education demonstrates a high degree of diversity in instructional design, research methods, and the competency focus examined (Aurelia, Santhalia, & Kristiyanto, 2023; Imron et al., 2025; Pohan et al., 2024). Each study employs different procedures, instruments, and analytical approaches, ranging from conceptual tests and attitude questionnaires to observation sheets, resulting in findings that are difficult to compare directly. Several studies on STEM and STEAM education have focused on a single scientific discipline (Hehakaya et al., 2022; Nasir, Widiatmono, & Kuswanto, 2025; Parameswari, Sutoyo, & Azizah, 2023). Differences in the contexts of physics, biology, and chemistry also lead to significant variations in implementation. Such diversity in instructional design, research methods, and assessed competencies makes it challenging to identify clear directions in the development of STEM research in science learning. A systematic synthesis is therefore required to integrate these findings comprehensively and provide a more focused and consistent overview.

While several reviews have addressed the application of STEM and STEAM in science education, these studies generally focus on learning effectiveness or specific implementation characteristics. Few studies have comprehensively mapped publication trends, the distribution of learning outcome domains (cognitive, affective, and psychomotor), implementation across science disciplines (physics, chemistry, and biology), research methodology characteristics, and the geographical distribution of studies within a single, integrated synthesis. The ongoing evolution of STEM and STEAM research in recent years highlights the need for an updated review to reflect current research directions. Therefore, this study focuses on articles published between 2021 and 2025 to provide an up-to-date overview of the characteristics and trends of STEM and STEAM research in science education.

This study aims to conduct a Systematic Literature Review (SLR) to map research trends on STEM and STEAM in science education (physics, chemistry, and biology) during the period 2021–2025. Specifically, the study analyzes publication trends by year, journal, publisher, and indexing status; the distribution of investigated learning outcome domains (cognitive, affective, and psychomotor); the implementation of STEM and STEAM across science disciplines; the characteristics of research methodologies and data collection techniques employed; and the geographical distribution of the countries in which the studies were conducted. This analysis is expected to provide a comprehensive overview of the characteristics, development, and research trends of STEM and STEAM in interdisciplinary science education. Based on these objectives, this study addresses the following research questions (RQ).

RQ 1: How is the trend of STEM/STEAM research publications in science learning reviewed from the perspective of year of publication, journal, publisher, and publication indexing?

RQ 2: How are STEM and STEAM approaches distributed across the examined learning outcome domains, including cognitive, affective, and psychomotor domains?

RQ 3: How is the implementation of the STEM/STEAM approach in science learning based on scientific fields, namely physics, chemistry, and biology?

RQ 4: What are the characteristics of STEM/STEAM research methodology in science learning? reviewed from a research approach?

RQ 5: What is the distribution of countries in which STEM/STEAM studies in science education have been conducted?

METHODOLOGY

This study employed a Systematic Literature Review (SLR) method following the standard procedures proposed by (Kitchenham, 2004). The literature search was limited to publications issued between 2021 and October 2025. The selected articles were retrieved online from the Scopus and ERIC databases using the keywords "STEM or STEAM" and "Science Learning OR Physics OR Biology OR Chemistry." The article search using these keywords was conducted in November 2025. The review process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The flow diagram illustrating the stages of the research process is presented in Figure 1.

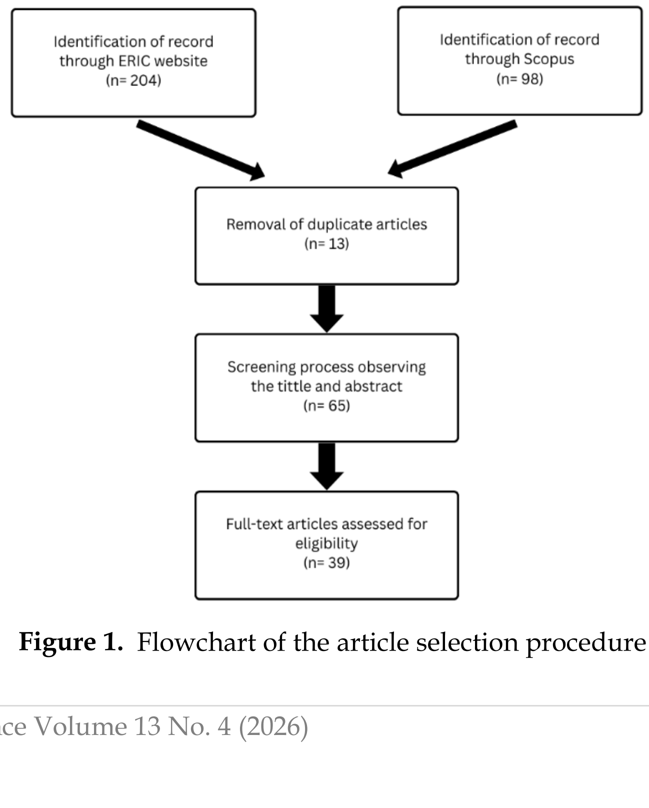

Figure 1. Flowchart of the article selection procedure

During the identification stage, research questions were formulated and relevant articles were retrieved from the selected databases. In the screening stage, articles were evaluated based on their titles and abstracts. Studies unrelated to STEM/STEAM in science learning, those not implemented at the secondary school level, review articles, books, book reviews, non–science education publications, and articles not written in English were excluded. The eligibility stage involved a full-text assessment of the remaining articles using predefined inclusion and exclusion criteria aligned with the research objectives and scope (Table 1). These criteria guided the selection process to ensure systematic and consistent screening. Eligible articles were further examined based on authorship, publication year, and research objectives to confirm their relevance. The inclusion criteria required that the studies report empirical findings directly related to the implementation of STEM or STEAM in learning contexts and exclude review or meta-analytic studies. Following this process, 39 articles were deemed eligible and included for further analysis

Table 1. Inclusion and Exclusion Criteria

Category	Inclusion Criteria	Exclusion Criteria
Language	English	Non-English
Publication Year	Year 2021-2025	Published outside the period 2021–2025
Educational Level	Secondary school	Preschool, Primary School, or Higher Education (University/College)
Independent Variable	STEM or STEAM	Not related to STEM or STEAM
Discipline	Science (Chemistry, Physics, Biology)	Outside the field of science.
Research Method	Reports an empirical research methodology and clearly describes the data collection instruments.	Does not include empirical data or fails to adequately describe the research methodology and/or data collection instruments.
Research Focus	Examines learning outcomes (cognitive, affective, and psychomotor domains).	Does not investigate learning outcomes.
Accessibility	Full text available	Full text unavailable

The subsequent step involved examining patterns emerging from the articles that passed the selection process. The analysis was conducted by organizing the data into relevant categories. This process aimed to identify general trends and variations in the characteristics of STEM/STEAM research in science education. The classified findings were then summarized to examine the proportional distribution across categories, thereby providing a systematic overview of research developments within the specified time frame.

FINDINGS

Trends in STEM/STEAM Research Publications

This systematic literature review examines 39 articles published between 2021 and November 2025. The reviewed articles focus on implementing STEM or STEAM approaches in science learning at the secondary school level. The selected time frame was intended to capture recent trends and to identify research directions over the past five years.

The articles analyzed in this study originate from a wide range of publication sources with varying levels of indexation, from nationally accredited journals to Scopus-indexed international journals. The processes of journal classification and identification are important steps in mapping publication trends and assessing the quality and credibility of scholarly sources contributing to STEM or STEAM education research. Analysis of publishers and indexation status further provides a more comprehensive understanding of the visibility, accessibility, and scholarly impact of these articles within the global academic community. This mapping not only illustrates the distribution of publications but also reflects the dynamics of knowledge dissemination and research trends in STEM and STEAM within the broader context of science education.

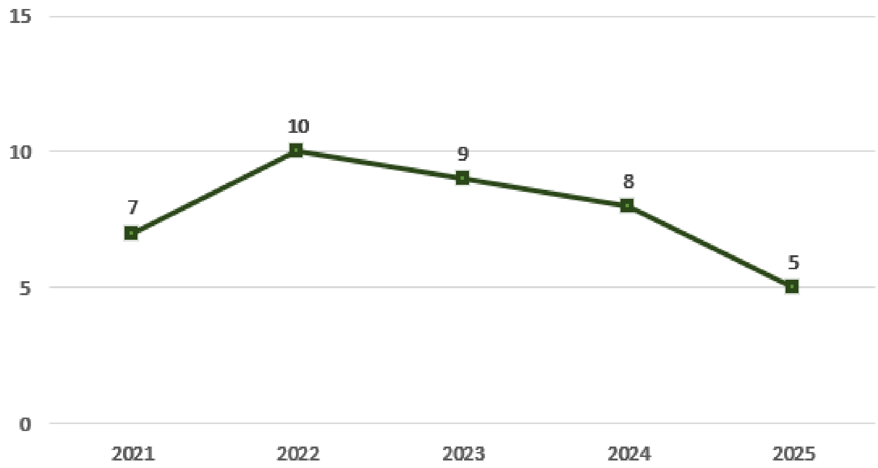

Figure 2. Distribution of Article by Year Published

Publication trends peaked in 2022 before gradually declining. Although this downward trend might suggest a temporary drop in publication volume, the relatively low figures for 2025 should be interpreted with caution, given that data collection took place before the year ended. Overall, the findings indicate that research on STEM and STEAM in science education remained consistently active throughout the five-year period, with publication numbers fluctuating rather than exhibiting a sustained upward or downward trend.

Table 2. Journal Distribution of Included Articles

Journals	Frequency	Years	Publisher	Indexing
Journal of Technology and Science Education	1	2024	Omnia Science	Q2
Journal of Science Learning	7	2024;2022;2022;2024; 2023;2022;2021	Universitas Pendidikan Indoensia (UPI)	non scopus (Sinta 2 Indexed)
Journal of Pedagogical Research	2	2023;2021	Duzce University, Faculty of Education	Q3
Journal of Turkish Science Education	1	2023	Firtina Academy	Q2
Science Insights Education Frontiers	1	2025	Insights Publisher	non scopus
European Journal of STEM Education	2	2021;2022	Lectito	Q1
Journal of Theoretical Educational Science	1	2023	Afyon Kocatepe University	non scopus
International Journal of Curriculum and Instruction	2	2022;2022	World Council for Curriculum and Instruction (WCCI)	non scopus
Science Education International	1	2025	International Council of Assosiation for Science Education (ICASE)	Q3
Educational Process: International Journal	1	2025	Universitepark	Q2
Journal of Baltic Science Education	3	2025;2021;2024	Scientific Methodical Center	Q2
International Journal of Education and Practice	1	2023	Conscientia Beam	Q3
Participatory Educational Research	2	2022;2021	Ozgen Korkmaz	Q3

Journals	Frequency	Years	Publisher	Indexing
Journal of Biological Education Indonesia (Jurnal Pendidikan Biologi Indonesia)	2	2023;2024	Universitas Muhammadiyah Malang	S2
European Journal of Science and Mathematics Education	1	2023	Bastas	Q2
European Journal of Educational Research	1	2022	Eurasian Society of Edicational Research	Q3
International Online Journal of Education and Teaching	1	2021	Ankara: İsmail Hakkı Mirici	non scopus
International Journal of Psychology and Educational Studies	1	2021	Elazığ: Bilge Akademik Yayıncılık Eğitim Bilişim ve Danışmanlık Hizmetleri LTD	non scopus
Education Sciences	2	2022;2024	Multidisicplinary Digital Publishing Institude (MDPI)	Q1
Sustainability (Switzerland)	1	2022	Multidisicplinary Digital Publishing Institude (MDPI)	Q1
Humanities and Social Sciences Communications	1	2023	Springer Nature	Q1
SAGE Open	1	2024	SAGE Publications Inc	Q1
Journal of Education, Culture, and Society	1	2025	Pro Scientia Publica Foundation	Q3
Frontiers in Psychology	1	2023	Frontiers Media SA	Q2
International Journal of Information and Education Technology	1	2024	International Journal of Information and Education Technology	Q3

The identification of the 39 reviewed articles reveals a notable difference in the proportion of STEM and STEAM approaches used in science education research. As illustrated in Figure 3, studies adopting the STEM approach account for a dominant 82%, whereas only 18% employ the STEAM approach. These findings indicate that the integration of the arts into science learning has not yet become a primary focus of research, while the application of the four core domains—science, technology, engineering, and mathematics—continues to dominate publication trends during the 2021–2025 period. The learning outcome domains were coded into cognitive, affective, and psychomotor categories based on Bloom's taxonomy. This classification provides an overview of research focus in the implementation of STEM/STEAM learning in science education. As shown in Figure 4, the cognitive domain is the most frequently examined, accounting for 62% of studies, followed by the affective domain at 23% and the psychomotor domain at 15%.

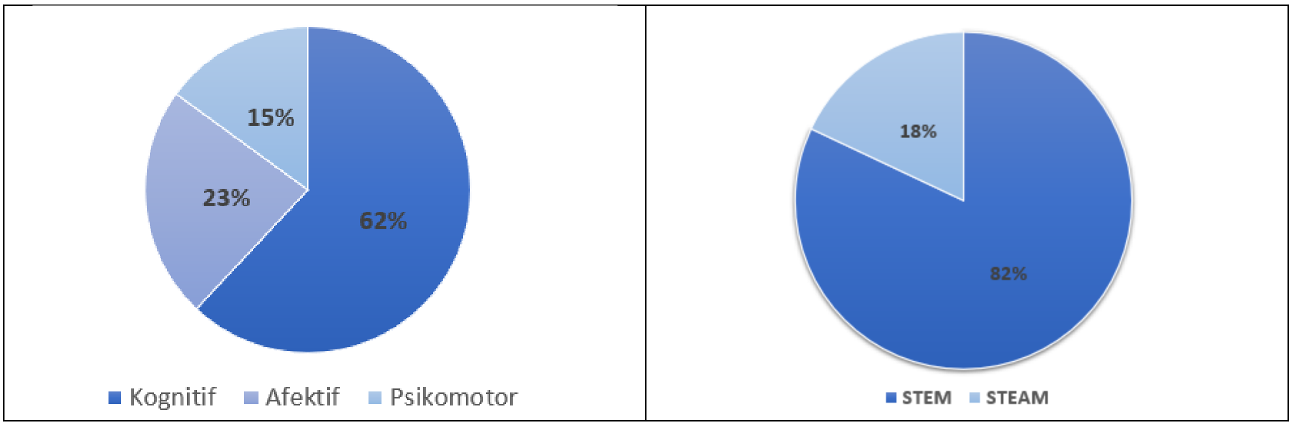

Figure 4. Distribution of STEM or STEAM education research domain

Based on the identification of science disciplines examined in STEM/STEAM research shown in Figure 5, physics represents the most frequently studied field. STEM/STEAM research is also found in biology, followed by chemistry, and integrated science. These findings indicate that STEM/STEAM research in science learning is distributed across multiple scientific disciplines, with varying proportions in each field.

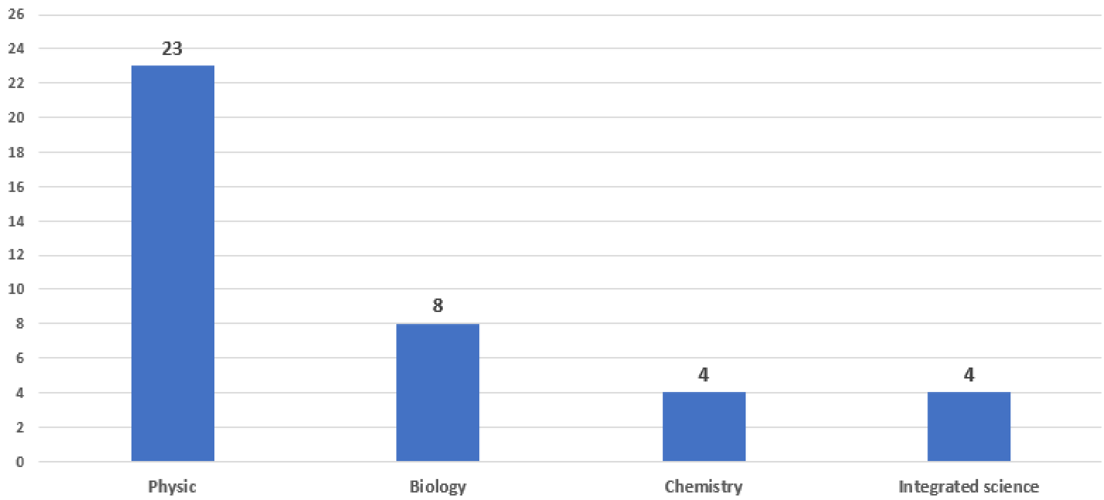

Figure 5. Distribution of Science Topics in STEM/STEAM Research

The analysis of research methods employed in the reviewed articles reveals considerable variation in methodological approaches within STEM/STEAM studies in science education. The identification of methodological approaches was based on the research designs declared in each article and was subsequently classified into four main categories, as presented in Table 3. The results indicate that articles employing quantitative approaches constitute the most dominant category, particularly those using experimental designs as the primary approach for evaluating the effects of classroom instructional interventions.

Table 3. The Trend of STEM or STEAM Education from Research Methods

Approach	Research Methods	Frequency	Percentage (%)
Quantitative	Experiment	28	72
Qualitative	case-study	4	10
The other	Mixed Method	5	13
	Research and Development	2	5

The countries where the studies were conducted were identified to map the geographical distribution of STEM/STEAM research in science education and to provide an overview of each country's contribution to the development of research in this field. Each article was classified based on its research location, as shown in Figure 6. The highest number of publications originated from Turkey, followed by Indonesia, while other countries exhibited more diverse and relatively lower levels of contribution.

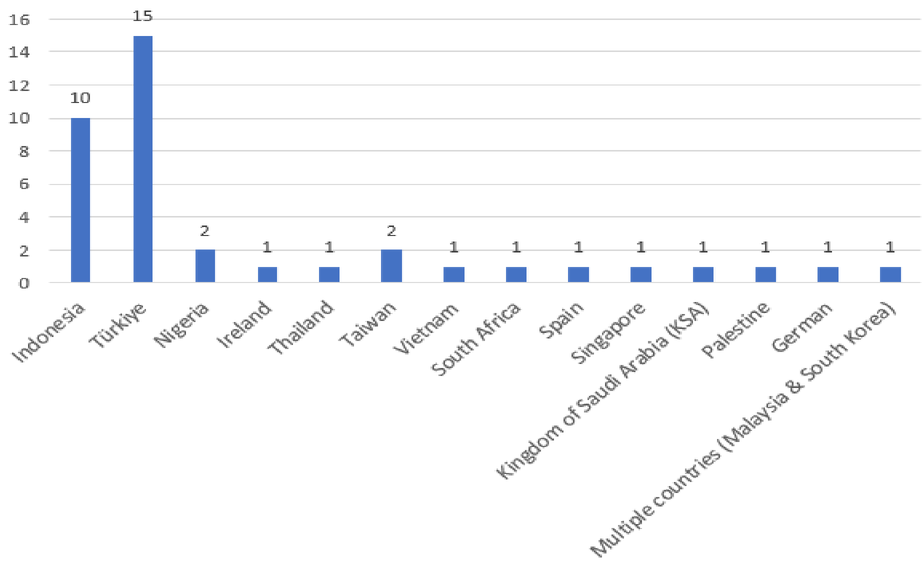

Figure 6. Country Distribution of STEM/STEAM Research

Figure 6 illustrates the geographical distribution of STEM/STEAM research in science education across various countries. The findings indicate that Turkey contributed the most studies, followed by Indonesia. This suggests that both countries have demonstrated significant research interest and active implementation of STEM/STEAM approaches in science education during the 2021–2025 period. In contrast, Nigeria and Taiwan each contributed two studies, while other countries, including Ireland, Thailand, Vietnam, South Africa, Spain, Singapore, the Kingdom of Saudi Arabia (KSA), Palestine, and Germany, as well as a collaborative study involving Malaysia and South Korea, were represented by a single publication each. This distribution indicates that STEM/STEAM research in science education has expanded across diverse geographical regions; however, research productivity remains uneven and concentrated in a select number of countries.

DISCUSSION

Trends in STEM/STEAM Research Publications

Trends in STEM/STEAM research publications during the 2021–2025 period generally show fluctuations. This indicates that research on the application of STEM/STEAM in science education remained consistent throughout the study period, despite year-to-year variations in publication volume. Such fluctuations suggest that interest in STEM/STEAM research continues to grow and remains a key focus within science education research. The dynamics of publication numbers also reflect the ongoing exploration of STEM/STEAM implementation across diverse learning contexts, subject matter, and educational levels, resulting in varied research outputs each year. This pattern aligns with bibliometric analysis findings (Nurazmi, 2025), which also documented STEAM publication activity during the observation period. These findings demonstrate that STEM/STEAM research is dynamic and continues to garner attention from the academic community as a relevant approach for enhancing the quality of science education.

The trends in STEM/STEAM research publications from 2021 to 2025 are also reflected in the diversity of publication outlets in which these studies were disseminated. This diversity indicates that STEM/STEAM research has attracted the interest of a broad range of academic communities and has been published across various scholarly platforms. The predominance of articles published in Scopus-indexed journals, including several highly reputable Q1 journals, suggests that STEM/STEAM research in science education has not only expanded in terms of publication output but has also been disseminated through journals that maintain rigorous methodological standards and robust peer-review processes. These findings indicate that the implementation of STEM/STEAM has become a well-established research area that is increasingly recognized within the international science education community

Focus of Approach and Domain of Learning Outcomes

The finding that the STEM approach predominates over STEAM indicates that research conducted between 2021 and 2025 has continued to focus on reinforcing core concepts in science, technology, engineering, and mathematics without explicitly incorporating the arts. Science curricula in many countries—particularly at the secondary school level—place greater emphasis on scientific literacy and conceptual understanding, which may explain why the integration of the arts is not yet viewed as a core necessity. Many STEM studies aim to enhance conceptual understanding, problem-solving, or critical thinking skills—outcomes traditionally more aligned with the STEM domain than with STEAM. Furthermore, implementing STEAM often requires more complex project designs and extended instructional time, factors that can limit its application in classroom-based research (Sanz-camarero, Ortiz-revilla, & Greca, 2023). This condition leads schools and researchers to favor STEM implementation, as it is generally easier to apply, evaluate, and report within formal research contexts. Nevertheless, the continued presence of STEAM studies (18%) indicates a growing interest in integrating creativity and aesthetic expression into science learning. Several previous studies have suggested that STEAM has the potential to enhance students' motivation, curiosity, and creativity; therefore, this trend may become more pronounced in future research periods (Gu et al., 2023; Hsiao & Su, 2021).

The dominance of studies targeting cognitive competencies indicates that the evaluation of STEM/STEAM learning remains largely dependent on conceptual understanding. This dominance is consistent with the characteristics of the cognitive domain in Bloom's taxonomy, which emphasizes thinking processes, reasoning, and conceptual mastery (Bloom et al., 1956). Furthermore, the characteristics of STEM learning, which emphasize conceptual understanding and scientific reasoning, make cognitive aspects more readily developed and measured through test-based instruments (Swandi, Sujiono, Khaeruddin, & Sinring, 2025; Wahyudi, Rusilowati, Nugroho, & Widiyatmoko, 2024). This reflects a tendency to measure the success of STEM/STEAM learning primarily by test results or academic achievement, rather than by the development of other competencies that are also goals of 21st-century education. In reality, the implementation of STEM/STEAM aims not only to enhance conceptual understanding but also to foster scientific attitudes, collaboration, creativity, and communication, as well as practical skills for solving real-world problems.

Some studies also combine measurements of the cognitive domain with those of the affective or psychomotor domains. The affective domain is typically measured via questionnaires evaluating learning motivation or data reflecting attitudes toward science, whereas the psychomotor domain is assessed using observation sheets that track student performance during the learning process or the execution of STEM projects. These findings indicate that STEM implementation is not solely aimed at enhancing conceptual mastery but also at developing students' attitudes and skills. However, research addressing the affective and psychomotor domains accounts for a smaller proportion than studies focused on the cognitive domain. Affective and psychomotor aspects are often viewed as supporting variables, leading researchers to prioritize changes in cognitive learning outcomes as the primary indicator of STEM program effectiveness (Mukherjee & Kittur, 2025). Future research needs to develop assessment instruments that measure the three learning domains more comprehensively, so that the impact of STEM/STEAM implementation on student development can be better understood.

Implementation of STEM/STEAM in the Field of Science

Physics is the most frequently examined science context, a fact that can be explained by its strong alignment with the principles of STEM and STEAM integration. Physics encompasses concepts that are closely related to technology, engineering, and mathematics, making it more readily developed through STEM- or STEAM-based project activities (Flores-godínez et al., 2025). Nevertheless, the dominance of physics in STEM/STEAM research does not imply that biology and chemistry are less relevant to these approaches. On the contrary, both disciplines continue to hold substantial potential for integration into STEM/STEAM learning, although they present different challenges than physics.

The implementation of STEM/STEAM in biology and chemistry appears less frequently in the reviewed literature. However, studies indicate that STEM/STEAM approaches can be effectively applied to both disciplines through instructional designs tailored to the subject matter's specific characteristics. STEM-based Problem-Based Learning has been reported to enhance student learning outcomes and retention (Birnin, Usman, Ali, & Ahmad, 2023). Inquiry-based STEM instruction in biochemistry facilitates the development of inquiry skills, scientific attitudes, and an understanding of the relationships between concepts (Lupión-Cobos, Girón-Gambero, & García-Ruiz, 2022). These studies demonstrate that STEM implementation can be adapted to various biological contexts using instructional strategies suited to the material being studied. The fact that research remains dominated by physics highlights an opportunity to expand STEM/STEAM implementation into biology and chemistry, thereby diversifying the empirical evidence across scientific disciplines.

Characteristics of Research Methodology

The most frequently employed research approach in STEM/STEAM studies is quantitative, particularly experimental methods. This trend indicates that STEM/STEAM research is generally directed toward examining the measurable effects of STEM/STEAM instruction on students' learning outcomes or skills. Experimental methods allow researchers to compare conditions before and after an intervention or between treatment and control groups using statistically analyzed numerical data. These findings are consistent with previous studies reporting that STEM/STEAM research in science education tends to emphasize the measurement of instructional effectiveness (Amanova et al., 2025; Chappell et al., 2025).

Although the findings indicate that research approaches are dominated by quantitative methods, qualitative approaches and other research methods also play a role in STEM/STEAM learning research, particularly in revealing learning processes, students' responses, and implementation contexts that cannot be fully explained through quantitative data. Studies conducted by Baydere & Bodur (2022), Rahmawati et al. (2024), 2022 Ter, Tan, & Lee (employed qualitative approaches to explore STEM and STEAM learning. In addition, mixed methods approaches are used to combine quantitative and qualitative data, thereby providing a more comprehensive understanding of the impacts of STEM/STEAM learning as well as the implementation process (Bakirci, Kirici, & Kara, 2022; Baykır, Mirici, & Sönmez, 2022; Lupión, Girón-Gambero, & García-Ruiz, 2022; Tiryaki & Adıgüzel, 2021; Yesildag-hasancebi et al., 2021). Research using research and development (R&D) designs conducted by Rahmayani, Kuswanto, and Rahmat (2024) and Sittisak and Roekmongkol (focuses on the development and validation of STEM/STEAM-based instructional materials before their implementation in learning.

Distribution of Countries Where STEM/STEAM Research Was Implemented

The geographical distribution of the reviewed studies indicates that STEM/STEAM research in science education has been conducted across various countries, although publication volumes vary significantly. This variation suggests that while STEM/STEAM research has garnered international attention, research activity remains concentrated in specific countries. Consequently, the existing literature reflects the educational contexts of certain nations more strongly than those of regions with fewer studies. The limited representation of many countries also indicates that evidence regarding STEM/STEAM implementation in science education is not yet evenly distributed across diverse educational settings. Therefore, caution is required when generalizing these findings to countries with different educational contexts. Increasing research in underrepresented nations would provide a broader understanding of STEM/STEAM implementation and enrich the evidence base derived from diverse educational systems.

Future research should expand the geographical scope of STEM/STEAM studies and incorporate more cross-country comparisons. Such studies would help identify similarities and differences in STEM/STEAM implementation across various educational contexts and contribute to a more comprehensive understanding of its application in science education.

CONCLUSION

Based on the results of a Systematic Literature Review (SLR), research on STEM/STEAM in science education during the 2021–2025 period indicates that this field continues to evolve and remains a topic of significant interest within science education research. The analyzed articles span various publication levels—ranging from Scopus-indexed journals to national journals—reflecting the diversity of sources in STEM/STEAM science education research. Regarding the approaches employed, STEM-based research articles outnumber those adopting the STEAM approach. Furthermore, research trends reveal that physics content continues to dominate STEM/STEAM-based science education; these studies generally focus on the development and assessment of students' cognitive domains. From a methodological perspective, quantitative research approaches—specifically experimental designs—are the preferred choice for evaluating the effectiveness of STEM/STEAM implementation. Additionally, the geographical distribution of research activity identifies Turkey as the country with the highest number of publications concerning the application of STEM/STEAM in science education.

The findings of this study provide a comprehensive overview of STEM/STEAM research in science education during the 2021–2025 period, serving as a foundation for identifying future research directions and developmental trends in the field. However, the study has limitations; as it includes only articles published between 2021 and 2025 based on established inclusion criteria, the resulting picture is confined to that specific scope and does not fully represent the entire trajectory of STEM/STEAM research. Consequently, future studies are encouraged to extend the timeframe, expand the database, and consider other publication types to achieve a more comprehensive mapping of STEM/STEAM research developments.

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