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Research Trends: STEAM Approach in Science Learning

Muhammad Ikhbar Ihsan[1], Parno[1*], Purbo Suwasono[1]

[1] Department of Physics Education, Faculty of Science and Mathematics, Universitas Negeri Malang, Malang, Indonesia.

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Corresponding Author:
Parno
parno.fmipa@um.ac.id

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Abstract: This study aims to examine research trends and explore the potential use of the STEAM approach in science learning. A Systematic Literature Review (SLR) was conducted using the PRISMA guidelines. The keywords "STEAM" and "Science Learning" were used to search the Scopus database, resulting in 60 articles, of which 13 met the inclusion criteria for further analysis. The findings highlight that the STEAM approach has strong potential to enhance science learning, particularly in improving students' 21st-century skills, conceptual understanding, and engagement through contextual and interdisciplinary learning experiences. This study is expected to serve as a valuable reference for researchers and educators in developing effective STEAM-based instructional strategies across various educational levels.

Keywords: Science learning; STEAM; Systematic literature review

Introduction

The rapid development of the times encourages the world of education to adapt (Astra, 2021; Khairullina, 2022). Today, students face increasingly complex challenges, so thorough mastery of competencies is needed to respond to the global dynamics of the 21st century (Matuk, 2024). In response to these challenges, education is required to present a learning approach that can develop critical, collaborative, and creative thinking skills through cross-disciplinary integration (Lafifa et al., 2022). One of the approaches that has been developed and is considered relevant in this context is the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach (McCormick, 2021; Zhang, 2024). This approach is a development of STEM that adds elements of art to strengthen students' creativity and imagination (Hasanah et al., 2023). Through the STEAM approach, science learning is no longer separate from the real world but is directly linked to everyday life problems and is designed to encourage problem-solving through exploration and collaboration (Benu et al., 2024).

Although this approach is increasingly being applied, a comprehensive study of the direction and trends of STEAM research in science learning is still not widely available (Chistyakov et al., 2023). In-depth literature mapping is essential to understand how this approach is evolving, the challenges faced, and the opportunities that can be leveraged in future learning development (Ng, 2024). Therefore, a systematic study is needed to examine the development of research related to the application of the STEAM approach to science learning. A Systematic Literature Review (SLR) is the appropriate method for thoroughly compiling and analyzing the literature (Magaji, 2024). By conducting an SLR, researchers can identify trends, patterns, and gaps in previous research (Guerra-Reyes, 2024). In addition, SLR helps lay a solid theoretical foundation for the development of advanced research (Yanti, 2024).

Based on this, this study was conducted to analyze research trends related to the STEAM approach in science education. This study is expected to provide a comprehensive overview of how the STEAM approach is applied in science education and contribute to the development of learning models that are more creative, contextual, and relevant to current needs. State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

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Method

This study uses a Systematic Literature Review (SLR) approach to evaluate the STEAM approach in the context of science learning (Hardianto et al., 2024). This research method followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Salim et al., 2024).

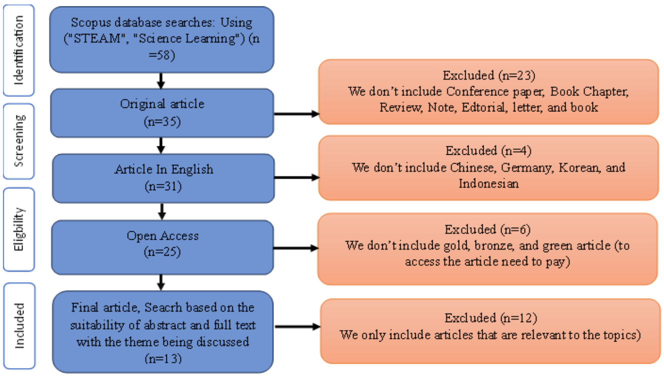

Figure 1. PRISMA diagram

Figure 1 presents the initial search stages conducted by the author through the Scopus database using the keywords "STEAM" and "Science Learning," which resulted in 58 articles. In the first screening stage, the author selected only the original type of article, so that the number of articles remained as many as 35, while the other 23 articles were excluded because they were included in the categories of conference proceedings, book chapters, literature reviews, notes, editorials, letters, and books.

Furthermore, the selection was based on the language of the publication. The author only considered articles written in English to avoid errors in interpretation. From this process, the number of articles was reduced to 31, with four articles not selected because they were written in German, Korean, Chinese, and Indonesian.

In the next stage, the author selected articles that have open access, so that the article can be accessed and used freely without having to pay. 25 articles were obtained, while six other articles were removed because they were included in the paid access category, such as gold, bronze, and green articles.

The final stage was carried out by reviewing the 25 articles through abstracts and the content of the text as a whole to assess their suitability for the research topic. Based on this assessment, 13 articles were declared relevant and met all the inclusion criteria, while the other 12 articles were not included because they were not in accordance with the theme of the study.

Result and Discussion

RQ1: Publication Trends of the STEAM Approach in Science Learning

The results of research on the STEAM approach in Science Learning were reported using SLR. Based on the analysis of data from research related to the STEAM approach in science learning, many articles from each year are shown in Figure 2.

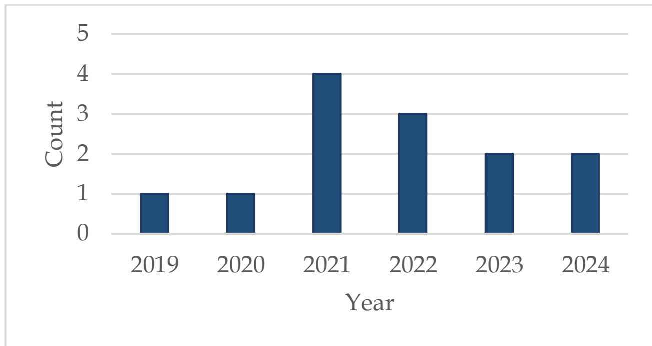

Figure 2. Distribution of Article Years

Figure 2 shows the number of articles discussing the STEAM approach in science learning from 2019 to 2024. It can be seen that publications fluctuate every year. 2021 recorded the highest number of articles, four publications, followed by 2022 with three articles. Meanwhile, 2019 and 2020 recorded only one article each. The number of publications decreased in 2023 and 2024, with two articles published each year. This pattern reflects that although the STEAM approach has gained attention, research interest in this topic has not consistently increased. Considering that the data were collected until the end of 2024, it is possible that there will still some articles will be published in 2025. The results of the review of 13 articles based on the type/research method on the theme of the STEAM approach in science learning are presented in Table 1.

Table 1. Types/methods of research

Method	n
Quantitative	3
Development	7
Experiment	2
Mix Method	1

Table 1 shows that 13 articles examined the STEAM approach in science learning. The most widely used development research method, which is as many as 7 articles. This indicates that the STEAM approach is widely used to design and develop learning tools and models. In addition, there are three articles that use quantitative methods, two articles that use experimental methods, and only one article that uses the mixed method.

Nationality of Researchers and International Collaboration

Research trends related to the nationality of researchers related to the theme of the STEAM Approach in science learning are shown in Table 2.

Table 2. Nationality and Continent of the Authors

Country	n	%
USA	9	22.5
Italy	7	17.5
Spain	6	15
Ireland	4	10
Portugal	3	7.5
Saudi Arabia	2	5
Greece	2	5
South Korea	2	5
Turkey	1	2.5
Germany	1	2.5
Netherlands	1	2.5
Vietnam	1	2.5
Australia	1	2.5

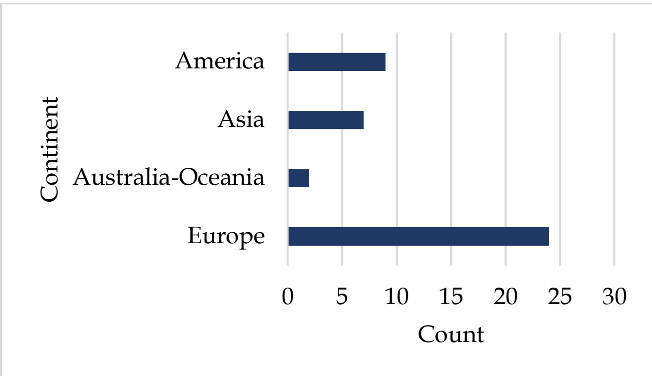

Figure 3. Number of authors from each continent

Table 2 presents the distribution of the author's country of origin which examines the theme "STEAM approach in science learning" shows that the United States is the country with the highest contribution, which is as many as 9 articles or 22.5% of the total publications. Italy ranked second with seven articles (17.5%), followed by Spain with six articles (15%). Other countries, such as Ireland (10%), Portugal (7.5%), Saudi Arabia, Greece, and South Korea, each contributed two articles (5%). Turkey, Germany, the Netherlands, Vietnam, and Australia each contributed one article (2.5 %). This shows that the STEAM approach to science learning has attracted the attention of researchers from various countries, especially Europe and America, and has begun to develop in several Asian countries and Australia. The distribution of the number of writers from each continent is shown in Figure 3.

The distribution of the number of author collaborations in articles discussing STEAM approaches to science learning is shown in Figure 4.

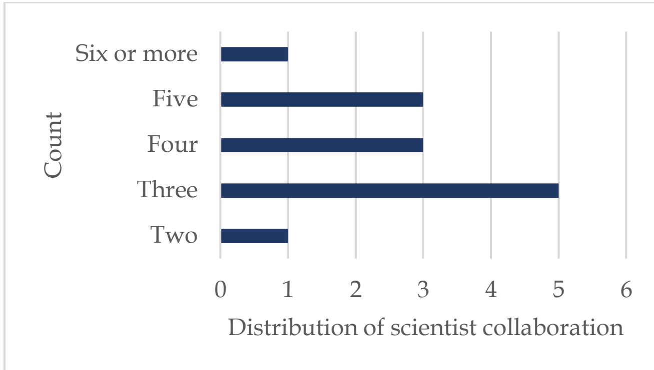

Figure 4. Researcher collaboration in writing articles

Figure 4 shows the collaboration of researchers in writing articles on the subject. The most research collaborations occurred with three authors, namely, five publications. Furthermore, collaborations involving four and five authors were recorded as three publications each. Collaborations involving two authors and six or more authors were found only once. This shows that most research related to the STEAM approach in science learning was conducted by small groups of three to five authors.

RQ2: The Potential of STEAM Approaches in Science Learning

The researcher reviewed 13 articles to identify and collect up-to-date information regarding the application of the STEAM approach to science learning. Four main points were obtained that explain the key aspects related to the integration of STEAM in science learning, as presented in Table 3.

Table 3. Important Findings from the Article

Information Found	Linkage to Information
The application of the STEAM (Science, Technology, Arts, Engineering, and Mathematics) approach in learning has a positive impact on cognitive creativity (especially in the "act" dimension or the active process of analogous thinking, idea generation, and concept manipulation) as well as students' motivation for science careers (Alexopoulos et al., 2021). The use of zines in STEAM motivates students to actively engage with science concepts through creative media (Brown et al., 2021). Integration of the arts (A in STEAM) does not reduce the focus on science, but instead helps students understand complex concepts and can reduce the	The integration of art in the STEAM approach provides space for students to explore creative expression, thus creating a more meaningful and immersive learning experience.

Information Found	Linkage to Information
learning gap between bilingual and English-speaking students (Hughes et al., 2022).	
The integration of art in STEM not only increases students' emotional engagement but effectively enhances scientific creativity and understanding of science concepts thereby helping students visualize abstract science concepts (Kim et al., 2023).	
The integration of SSI and STEAM helps students understand abstract science concepts more easily (e.g., using visual art to explain molecular structures) (Mang et al., 2021).	
The application of Augmented Reality (AR) technology in STEAM-based learning improves students' learning retention and critical thinking skills (Alkhabra et al., 2023).	The STEAM approach that focuses on aspects of technology and digital innovation provides opportunities for students to develop abstract and practical skills that are relevant to the development of science as well as the needs of the modern world
IoT and STEAM integration enhances Team Collaboration in designing and testing technology solutions, enabling students to explore innovative ideas, and improving digital literacy (Santos et al., 2023)	
STEAM activities based on eco-friendly straws as a science learning tool to improve students' Basic Science Process Skills (BSPS) (Khamhaengpol et al., 2024)	
STEAM learning interventions are considered effective in reducing the gap between bilingual learners (Emerging Bilingual Learners) and English speaking students (English Fluent Students) (Corrigan et al., 2022).	The STEAM approach provides opportunities for students to develop skills that are essential to the challenges of the 21st century through relevant and meaningful science learning.
Exploring the use of stand-up comedy adapted to the STEAM approach as a method to bring science closer as an activity that involves creativity, teamwork, and communication is not just an experiment in the laboratory (Heras et al., 2020).	
STEAM effectively enhances understanding of science concepts and 21st century skills (creativity, collaboration, problem-solving) (M. Liu et al., 2018).	
STEAM professional development programs have a significant effect on improving teachers' self-efficacy in applying STEAM methods in the classroom (Romero-Ariza et al., 2021).	The STEAM approach provides support for teacher professional development while strengthening student understanding through integrated and contextual learning.
STEAM integration effectively improves understanding of mathematical concepts when associated with real context (such as cryptography) and creative activity (Roldán-Zafra & Perea, 2022).	

Discussion

RQ1: Publication Trends of the STEAM Approach in Science Learning

Year Distribution

Thirteen articles discuss the application of the STEAM approach in science learning, showing a pattern that fluctuates from 2019 to 2024. Although there has been no consistent increase every year, the trend over the past two years indicates steady interest from researchers. This shows that STEAM is increasingly recognized as a relevant approach to be developed in the world of science education, especially in creating more innovative learning experiences (Cheng, 2022; Ng, 2024).

These developments illustrate that the STEAM approach plays an important role in strengthening students' understanding through the integration of science, technology, engineering, art, and mathematics (H. Lin, 2022; Weng, 2023). With this interdisciplinary approach, students are trained to think critically and creatively and work together to solve complex problems (Rohman, 2024; Trisnaningsih et al., 2021). The stability of researchers’ interest in this theme is a strong basis for the development of more holistic and contextual science learning practices in the future (Illene, 2023).

Type/Method of Research

Based on the results of the analysis of the research methods used in the study of the STEAM approach in science learning, it can be seen that there are variations in the approaches chosen by researchers. Of the 13 articles analyzed, most used the development method (7 articles), followed by quantitative (3 articles), experimental (2 articles), and mixed methods (1 article). This pattern suggests that most researchers focus on the creation or development of learning tools as an implementation of the STEAM approach (Cheng, 2022; Susanti, 2023).

In addition to the predominant development methods, quantitative and experimental methods also contribute to the objective validation of the effectiveness of STEAM implementation through numerical data (Alfian et al., 2024). Experimental methods help identify the direct influence of the STEAM approach on students' abilities, while quantitative methods are used to systematically measure certain aspects, such as learning outcomes or student responses (Yang, 2023). Although still very limited, the existence of research using mixed methods shows the potential for perspective enrichment. By combining quantitative and qualitative data, a more complete picture is provided. The combination of these methods is the foundation for the development of more in-depth and diverse follow-up studies in future STEAM research (Nafidiah et al., 2023; Parno et al., 2020) .

Collaboration

Table 2 shows the geographical distribution of authors, showing that the United States is the country with the most contributions, with as many as nine authors (22.5%). Italy ranked next with seven authors (17.5%), followed by Spain with six authors (15%). Other countries, such as Ireland, Portugal, Saudi Arabia, Greece, and South Korea, have two to four writers. Meanwhile, some countries are represented by only one author, so it can be said that their participation is still very limited in the study of the STEAM approach in the field of science learning.

Figure 3 shows that the dominance of researchers from the United States can be attributed to the application of the STEAM approach, which was introduced earlier in their education systems (Ramsey, 2022). In the United States, learning is already being implemented, focusing not only on memorizing materials but also on developing high-level thinking skills, creativity, and collaboration through the integration of various disciplines (Corrigan et al., 2022; Herwinarso, 2023). Additionally, an educational culture that supports experimentation and innovation provides space for teachers and researchers to develop new learning methods (Sormunen, 2023). However, in countries with a small number of writers, the STEAM approach has not been widely studied because the curriculum tends to prioritize content over process skills (Nungu, 2023; Zuhri, 2023). The lack of teacher training in the implementation of STEAM and the limited understanding of its benefits for students (Boice et al., 2021). This condition opens up space for researchers from the region to further explore the potential of STEAM approaches in science learning in the future (Hamad et al., 2022).

Figure 4 shows that the majority of scientific publications in the data analyzed involved three to five authors, with the largest number being in the collaboration of three. This reflects the increasing trend of collaboration in research, especially in the increasingly complex and multi science (Dusdal & Powell, 2021). The large number of authors in a single article, even up to six or more, can be due to the need to combine a wide range of expertise from different disciplines and the involvement of researchers from different countries (Ivanov et al., 2021). Cross-border collaboration allows for a wider knowledge exchange, better utilization of research facilities, and more effective global problem-solving (Beck et al., 2022; Sebatana, 2022). Thus, the involvement of multiple authors in a single scientific article not only demonstrates close scientific cooperation but also reflects a strategy to produce publications that are of high quality, globally relevant, and have a wider impact on the development of science.

RQ2: The Potential of STEAM Approaches in Science Learning

The STEAM approach, which incorporates elements of art, gives students the opportunity to develop their imagination and channel their ideas creatively (Aerila, 2023; C. Y. Liu, 2022). Art acts as a bridge between abstract concepts and real applications, allowing students to express their understanding through visual, music, movement, and other media (Chu, 2022). Through this process, students learn cognitively, emotionally, and aesthetically (H. Sari, 2024). Learning also becomes more lively, contextual, and fun because students feel personally involved in each activity (Paolucci, 2021). Thus, integrating art into STEAM enriches the learning experience and helps students build a deeper understanding of the material being studied (Horvath, 2023).

The STEAM approach's focus on digital technology and innovation opens up opportunities for students to familiarize themselves with digital tools that are now integral to everyday life (Khairullina, 2022). Through learning activities that involve the use of software, interactive applications, or digital simulations, students are encouraged to think logically, solve problems, and understand scientific concepts more concretely than before (Wannapiroon & Pimdee, 2022). Experience shapes theoretical understanding and develops applicable technical skills (Körtesi et al., 2022). Thus, students gain provisions to face the development of science and the challenges of the world of work, which is increasingly based on technology and innovation.

Students are required to possess skills that are not only academic but also include the ability to think critically, collaborate, communicate, and innovate (Wilson et al., 2021). Through the STEAM approach, students are trained to explore problems in depth, design solutions through project activities, and work in teams (C.-L. Lin & Tsai, 2021). This process forms a habit of reflective and systematic thinking, which is indispensable in the face of future challenges (Li et al., 2022). In addition, learning becomes closer to daily life, so that students can see the connection between science and social realities. Thus, the STEAM approach supports the formation of an adaptive, creative, and resilient generation across various situations (Belbase et al., 2022).

The implementation of the STEAM approach not only impacts students but also drives teachers to improve their competence (Kastriti et al., 2022; Razi & Zhou, 2022). Teachers are required to design cross-disciplinary learning that is interesting and relevant, as well as utilize various media and technologies (Dubek et al., 2021). Teachers are encouraged to be reflective and innovative in their teaching practice (Bertrand & Namukasa, 2023). On the other hand, students benefit from learning that is integrated into a real and easy-to-understand context (Duong et al., 2024). The quality of education improves when teachers and students grow through a dynamic learning process. The STEAM approach fosters synergy between teachers and students to create meaningful learning experience (Chapman, 2021).

In line with the growing interest in the STEAM approach, the results of a systematic literature review (SLR) conducted in this study show that research related to STEAM in science education has experienced a significant increase in the last five years, particularly at the secondary school level. Most studies focus on improving students' creative thinking, scientific literacy, and problem-solving abilities through project-based learning models (Benu et al., 2024; Indrasari et al., 2020; Rohman, 2024). However, the majority of research is still concentrated in developed countries, indicating a gap in implementation and study in developing regions, which presents a valuable opportunity for future research expansion (Wong, 2023).

Despite the promising potential of the STEAM approach, several challenges still hinder its optimal application. One of the main obstacles identified in the literature is the limited pedagogical understanding among educators regarding how to design and implement STEAM-based learning effectively (Razi & Zhou, 2022). In addition, constraints related to the availability of teaching materials, limited access to interdisciplinary learning tools, and a lack of institutional support are frequently mentioned. These challenges highlight the need for structured teacher training, the development of integrated curriculum guidelines, and stronger collaboration among stakeholders to ensure that STEAM can be implemented sustainably.

In conclusion, the STEAM approach has shown considerable potential to transform science learning into a more integrated, creative, and relevant process (Wikoff, 2021). However, realizing this potential requires collaborative efforts in research, curriculum development, and educator empowerment (Lindsay, 2021). The findings from this review can serve as a reference for education stakeholders to strengthen the design and implementation of STEAM-based learning, particularly in contexts that have been underrepresented in existing studies (Merrill, 2024). Through this, it is expected that the development of learning models will be increasingly responsive to the needs of the 21st century and contribute to the formation of a generation that is critical, innovative, and adaptable (Widarwati, 2021).

Conclusion

This SLR provides an interesting overview of research trends related to the STEAM approach to science learning. First, the number of publications on this topic shows a trend that tends to increase from year to year, although there are slight fluctuations in certain periods. Second, development research dominates the type of research used, followed by quantitative research, experimental research, and mixed methods, which show various approaches to exploring the effectiveness and application of STEAM . Third, the study found that publications related to this topic originated from various countries, with most authors coming from the United States. When viewed by region, this trend reflects the broad interest of researchers in Europe in developing STEAM approaches. Fourth, most articles are written through inter-agency and cross-country collaborations, showing that this issue is global and multidisciplinary. The researcher also succeeded in identifying the potential implementation of the STEAM approach in science learning, including encouraging students' creative exploration through the integration of the arts, strengthening conceptual understanding through project-based activities, and improving 21st century skills that are highly relevant to today's needs. In addition, this approach opens up more contextual and innovative learning opportunities, both in the school environment and at the level of the broader educational community. These findings reinforce the importance of developing and implementing the STEAM approach more widely, and provide a basis for further research in science learning.

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Author Contributions
Conceptualization, M.I.I. and P.; methodology, M.I.I.; validation, P. and P.S; formal analysis, M.I.I; investigation, M.I.I; resources, M.I.I.; data curation, M.I.I.; writing—original draft preparation, Muhammad Ikhbar Ihsan; writing—review

and editing, M.I.I.; visualization, M.I.I. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest.

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