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Trend of STEAM Research in Elementary Science Education: A Bibliometric Analysis

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Abstract: This bibliometric analysis examines research trends in STEAM (Science, Technology, Engineering, Arts, Mathematics) in primary school science education based on articles indexed in Scopus from 2016 to 2025. The research method employed bibliometric analysis using Publish or Perish and VOSViewer software to map productivity, author collaboration, and geographical distribution. The results show a significant increase in publications since 2019, with the United States as the leading contributor. The research focus has shifted from developing the STEAM concept towards evaluating the effectiveness of its implementation, particularly during the COVID-19 pandemic. This study identifies a gap in evaluative research on the impact of STEAM on learning outcomes and student engagement. The conclusion emphasizes the need for further studies that integrate impact analysis to strengthen the adaptation of the STEAM approach in education.

Keywords: Elementary School; Bibliometric Analysis; Science Education; STEAM

Introduction

The technological transformation taking place in today's society has brought great changes not only in the economic sector, but also in the world of education (Anisimova et al., 2020). There's a critical distinction in learning styles within the 21st century. Current learning styles center on preparing learners with 21st-century aptitudes, which combine a extend of information, capacities, habits and character characteristics to explore life within the cutting edge world of instruction. Subsequently, learners must have information from a wide extend of subject ranges to induce on in life and offer assistance them survive in a fast-paced world (Rahman, 2019).

The global employment landscape is rapidly transforming due to globalization and the industrial revolution, rendering many conventional professions obsolete while creating new fields of work. In facing this disruption, traditional instruction oriented towards coordinated labour is no longer sufficient to meet societal demands. In response, STEAM (Science, Technology, Engineering, Arts, and Mathematics) education has emerged as an innovative educational strategy. Designed to foster new professional fields through cross-disciplinary integration, STEAM equips learners with the analytical capabilities, creativity, and problem-solving competencies necessary to thrive in the modern era (Huang, 2020; Papadopoulou, 2024).

Rooted in constructivist principles, STEAM education posits that knowledge is actively constructed by learners through direct experience in projects that integrate all five disciplines (Adriyawati et al., 2020). The STEAM approach emerged as an innovative educational strategy capable of transforming basic education through integrated learning (Gonzales et al., 2025). This approach is particularly relevant in Natural Science (IPA) education at the elementary school level, where abstract concepts are often perceived as difficult (Faisal & Martin, 2019). By contextualizing science through

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technology, engineering, arts, and mathematics, STEAM can make science learning more meaningful, engaging, and conducive to deep conceptual understanding rather than rote memorization (Sulikah et al., 2020; Santi et al., 2021).

STEAM-based education is one of the innovations designed to meet the challenges of the digital era and address the needs of the 21st century (Papadopoulou, 2024). It is an innovative interdisciplinary integration that focuses on problem solving closely related to learners' experiences, both from concepts, principles of science, technology, engineering, art, and mathematics. STEAM education is used in the development of a product, process, and system that can be used in an integrated manner to hone students' ability to compete (Tabiin, 2020). Combining five disciplines (science, technology, engineering, arts, and mathematics) integrated into STEAM aims to provide students with skills and innovation in learning (Erol et al., 2023).

STEAM education encourages students to learn to explore all their abilities in their own way. The focus of the STEAM approach at each level of education must be adjusted to the cognitive thinking ability of students (Belbase et al., 2022). The integration of STEAM-based education at the early education level emphasizes student interest through learning activities that can stimulate curiosity (Mu'minah & Suryaningsih, 2020). The integration of the STEAM approach in lower education focuses on learning the principles of STEAM knowledge, then the knowledge is related to conditions in everyday life through learning activities. The integration of the STEAM approach in education aims to enable students to contribute to productivity and innovate for a more modern world of education (Santi et al., 2021). In the STEAM context, learners not only learn science or math theories, but also put them into practice in projects that involve elements of technology, engineering and art (Adriyawati et al., 2020).

Science learning or Natural Sciences (IPA) is known as knowledge about the universe, natural phenomena, and all the contents of the universe. Science in schools is a process of research and observation of natural phenomena, which is the main basis taught to students so that they are able to understand scientific concepts in depth rather than just memorizing (Budiyanto et al., 2022; Fakhriyah et al., 2025; Tami et al., 2023). Natural Science learning in elementary schools is often considered difficult because of the many abstract concepts that must be understood by students (Faisal & Martin, 2019). Science at the elementary school level is taught through the process of observing and researching natural phenomena, so that students can understand science concepts capably and not just memorize (Sulikah et al., 2020; Fakhriyah et al., 2025). The STEAM approach enables interdisciplinary science learning, where science is not taught as a stand-alone concept, but is linked to technology, engineering, art, and mathematics (Santi et al., 2021).

Although STEAM research and implementation have grown exponentially since 2016 (Glass & Wilson, 2016), significant theoretical and practical gaps remain. The novelty of this research lies in its effort **to** comprehensively and systematically map the research landscape of STEAM specifically within the context **of** *elementary school science education*. Previous bibliometric studies have tended to examine STEAM within broader educational scopes. This study aims to narrow that focus, identifying unique research clusters, trends, and collaborations at the intersection of "STEAM", "elementary education", and "science learning." In other words, this research does not just look at the general 'tree' of STEAM but specifically examines this crucial and distinct 'branch'.

The logical reasons why this study is important to conduct are identifying Specific Research Gaps: While much research discusses STEAM implementation in secondary or higher education, or in elementary education generally, this study will reveal the specific themes, challenges, and opportunities that have been explored—or neglected—in applying STEAM to *elementary science*. This will provide clear direction for future researchers.

Mapping Contextual Challenges in Developing Environments: Literature indicates that understanding the adaptation and functionality of STEAM in various educational environments, especially in developing countries, remains limited (Septiadevana & Abdullah, 2024). This bibliometric analysis can help identify the gaps between global research trends and local needs, as well as specific challenges (e.g., resource availability, teacher training) that may not be reflected in dominant research.

Providing an Empirical Foundation for Policy and Curriculum Development: By identifying proven effective trends and under-researched areas, the findings of this study can serve as an empirical foundation for policymakers, curriculum developers, and educational practitioners to design more targeted, effective, and contextually appropriate strategies for implementing STEAM in elementary science education.

Optimizing Future Research Directions: By visualizing collaborative networks and trending keywords, this research will highlight "hot topics" and underexplored "research gaps." This will help avoid duplication of effort and inspire new, more innovative, and impactful research themes.

Therefore, using a bibliometric analysis method, this study aims to quantitatively and qualitatively analyze and map STEAM research trends in elementary school science learning. The results are expected to provide a comprehensive roadmap for advancing the quality of research and educational practices aligned with the demands of the Society 5.0 era.

Referring to the research introduction that has been presented, the research focuses on exploring publication trends on STEAM research in elementary school science education by surfacing various keywords related to learner engagement, self-efficacy, and critical thinking. Thus, the purpose of this study is to answer:
How has the development of scopus indexed scientific publications on the topic of STEAM Research in Elementary Science Education over the past 10 years?
What is the distribution of countries based on the publishers of STEAM Research in Elementary Science Education topics?
How is the development of bibliometric networks and research trends on the topic of STEAM Research in Elementary Science Education?

Method

Research Design

This study uses a bibliometric approach to analyze the development of literature in the field of STEAM in elementary school science education. Data were obtained from the Scopus indexed database using the Publish or Perish (PoP) application by applying a search strategy using a combination of keywords "STEAM AND Elementary Science Education", as well as publication year restrictions with a range of 2016 to 2025. The data selection process was carried out by applying inclusion criteria, with the help of bibliometric analysis using VOSViewer to be able to map publication productivity, author collaboration networks, country distribution based on publishers, and relationship patterns between concepts through co-word and co-citation visualization (Aria & Cuccurullo, 2017). Data collection is done with the help of the Publish or Perish (PoP) application to find relevant articles using the Scopus database. The results of this analysis are expected to identify research trends, main contributors, and research gaps that have not been widely explored (Aria & Cuccurullo, 2017).

Research stages

The stages and steps of bibliometric analysis have four stages: (1) Determining research objectives; (2) Data collection; (3) Analysis and visualization; and (4) Interpreting research findings and results (Öztürk et al., 2024). After determining the research objectives, the stage begins with data collection using Publish or Perish (PoP) with the Scopus database. Researchers entered strategic keywords relevant to the research topic, namely "STEAM AND Elementary Science Education", and year filters with a range of 2016 to 2025, namely the last 10 years, including title, author, abstract, keywords, publication year, and number of citations. All metadata obtained is then exported in RIS format for further processing using the VOSViewer application. The advantage of using Publish or Perish (PoP) lies in its ability to overcome the limitations of exporting data directly from Scopus, while providing initial analysis such as citation trends and author productivity (Michael Hall, 2011).

Data analysis

The results of the analysis are then visualized in the form of interactive network maps. Co-occurrence maps reveal thematic clusters such as the integration of arts in science and the use of digital technologies, where the size of the nodes indicates the frequency of occurrence and the lines between nodes represent the strength of the relationship. Meanwhile, the co-citation map helps identify the works and collaboration patterns of researchers. These findings were then interpreted to identify key trends, such as the increasing interest in technology in STEAM learning, as well as potential research gaps. In the final stage of the analysis, the network maps from VOSViewer were exported in image format and accompanied by an explanation of the main clusters and research implications.

Result and Discussion

The analysis revealed a clear increase in the number of publications on STEAM research in primary school science education over the past decade. Scopus database results on keywords and publication range in the last 10 years showed a total of 117 publications as shown in Figure 1.

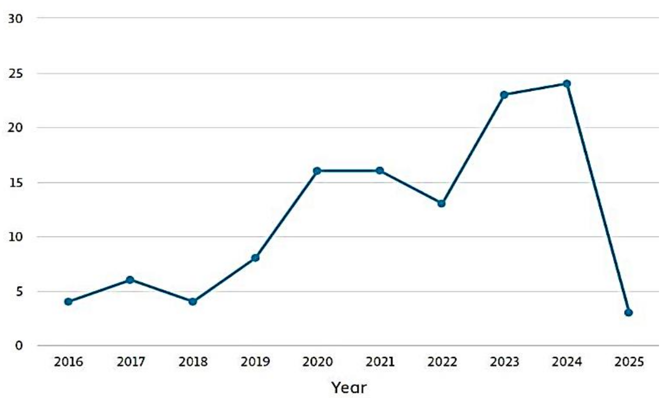

Figure 1. Development of Publications by Year of Publication
Source: Scopus Database

Figure 1 shows the general number of studies related to STEAM research trends in elementary school science education in the period 2016 to 2025. This development is in line with the findings of bibliometric studies that examine the patterns and dynamics of academic literature development. The variation in the number of studies conducted indicates a shift in research priorities and increased attention to the issue of STEAM-based learning in elementary school science education. The bibliometric approach allows the identification of various variables that play a role in fluctuations in research productivity (Gonzales et al., 2025). Details of the number of publications per year can be seen in Table 1.

Table 1. Details of the Number of Publications by Year of Publication

Publication Year	Number of Publication	Percentage (%)
2025	3	2
2024	24	21
2023	23	20
2022	13	11
2021	16	14
2020	16	14
2019	8	77
2018	4	3
2017	6	5
2016	4	3
Total	117	100

Table 1. the data shows that in 2016 to 2018 the number of publications is still very low because in this period, the STEAM concept is still relatively new in the world of global education and research, so adoption and publications are still limited. In 2019 to 2020 there began to be a noticeable increase in publications because it was a time when the STEAM approach began to get more attention, supported by the need for innovation in education and the integration of art in STEM, this was supported by the development of STEAM with Art-based technology (J.-O. Kim & Kim, 2018). STEAM research interest has started to increase since 2006 until now, but the resulting STEAM research interest has not been organized and has not been seen (Marín-Marín et al., 2021). Then in 2020, the covid-19 pandemic encouraged many technology-based learning innovations and creativity, including research on STEAM. In 2021 to 2022, the number of publications was stable although there was a slight decrease due to research at the beginning of the pandemic, many research focuses shifted to other topics such as the effectiveness of online learning, causing the growth of STEAM publications to slow down. In 2023-2024, there was a sharp increase, these years signaling global recovery from the pandemic. Many countries are adopting STEAM-based curricula to restore the quality of education and prepare an innovative generation. Support from education policies in various countries also encourages more research in this area. In 2025, it is still early in the year when data is collected from Scopus so that the data has not been fully inputted.

Publications were relatively low in the early years, with only 4 publications in 2016 and 2018, indicating limited academic interest in that period. However, a significant increase began to occur in 2019 with 8 publications, followed by a steady increase in the following years. The highest number of publications occurred in 2024 with 24 publications and 23 publications in 2023. This surge indicates the growing recognition of the importance of the STEAM (Science, Technology, Engineering, Arts, Mathematics) approach in primary school education. This is driven by the global emphasis on interdisciplinary learning and 21st century skills that implement STEAM in the learning process (Pahmi et al., 2022).

In 2020 and 2021, there were 16 total publications each, reflecting a consistent research focus despite the major challenge of the covid-19 pandemic. A sharp increase in 2022 with 13 publications, 2023 with 23 publications, and 2024 with 24 publications confirms a strong and significant expansion in academic activity, impacted by advances in digital learning tools, policy support for STEAM integration, and the need for innovative pedagogical education (Kang, 2019). The 3 publications already published in 2025 (as of the data collection period) further confirms the continued momentum in the area of STEAM research trends.

This trend is in line with the global educational shift that emphasizes experiential and project-based learning, as well as the integration of arts into STEM to encourage creativity and critical thinking (Adriyawati et al., 2020). This data not only demonstrates the growing academic interest in STEAM in primary science education, but also illustrates and hints at opportunities for further research, especially in areas that are still underrepresented such as cultural relevance, teacher training, and long-term impact assessment, these findings provide a basis for further bibliometric mapping, thus shaping this growing field. This finding is interesting, because in general, research using bibliometric analysis only describes popular affiliations that publish related to STEAM (Phuong et al., 2023), without explaining in detail the trends in research conducted related to STEAM.

Based on the results of database analysis from Scopus related to the distribution of publications by region, 117 publications were identified. The 10 countries with the highest number of publications are presented in Figure 2.

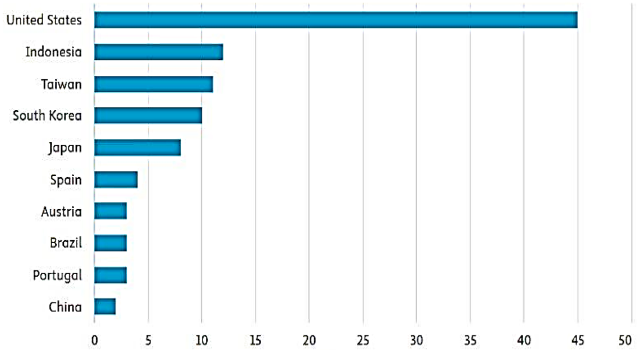

Figure 2. Publications by Country
Source: Scopus Data Base

Based on the geographical distribution of STEAM research in primary school science education, it can be seen that the United States dominates significantly with 45 publications, far exceeding other countries. Most publications in STEM education research are contributed by authors from the United States, where STEM and STEAM education originated (Li, Froyd, & Wang, 2019; Li, Wang, & Xiao, 2019). The second position is occupied by Indonesia with a contribution of 12 publications, followed by Taiwan with 11 publications and South Korea with 10 publications. The dominance of the United States at twice the rate of other countries indicates academic leadership and a mature research infrastructure in the field of STEAM education. At the same time, authors in some regions in Asia have become very active in this area over the past few years. This trend is consistent with findings from the IJ-STEM review (Li, Froyd, & Wang, 2019).

There is strong performance in East Asia with Taiwan, South Korea and Japan showing a regional commitment to STEAM education (Li et al., 2020). Indonesia's surprising second place reflects the implementation of an independent curriculum with STEAM emphasis in the 2022 Ministry of Education and Culture survey. The relatively low representation of Europe (only Spain and Austria) suggests a different focus on STEAM approaches in the region. The overall data is presented in Table 2.

The data in table 2 shows that there are 10 countries with the most publications on the topic of STEAM Research in elementary school science education. 10 countries have each had a percentage of publications, namely the United States as many as 45 publications (38.46%), Indonesia as many as 12 publications (10.25%), Taiwan as many as 11 publications (9.40%), South Korea as many as 10 publications (8.54%), Japan as many as 8 publications (6.83%), Spain as many as 4 publications (3.41%), Austria, Brazil, and Portugal as many as 3 publications (2.56%), and finally China as many as 2 publications (1.70%).

Table 2. Percentage of Publication Distribution Data by Country

Country	Documents
United States	45
Indonesia	12
Taiwan	11
South Korea	10
Japan	8
Spain	4
Austria	3
Brazil	3
Portugal	3
China	2
Israel	2
Luxembourgh	2
Malaysia	2
Vietnam	2
Bahrain	1
Colombia	1
Finland	1
Greece	1
Hongkong	1
Hungary	1
India	1
Ireland	1

Source: Scopus Data Base

Mapping the geographical distribution of scientific publications on STEAM Research in elementary school science education provides valuable insights into the dynamics of research in the field of 21st century education. Through a bibliometric analysis approach, it can find out how the contribution of each country shapes academic development on the topic (Wulan Aulia Azizah & Nur Indah Wahyuni, 2024).

Findings based on the data show that this STEAM research trend is spread globally, covering parts of Europe to Asia, which indicates that STEAM research trends have become a cross-country concern in the education system. The United States dominates the highest number of publications, which may reflect the country's strong commitment to strengthening STEAM-based education in basic science learning, as well as the birthplace of STEM and STEAM education (Li, Froyd, & Wang, 2019; Li, Wang, & Xiao, 2019). On the other hand, the region's apparent low share of STEAM publications suggests challenges in terms of research funding and different academic research resources.

A more in-depth study through bibliometric analysis can explore the correlation between a country's researcher productivity and certain constraining factors, such as uneven implementation of educational policies on STEAM integration, budget allocation for educational research, international academic collaboration networks, and research support infrastructure (Gonzales et al., 2025). This bibliometric analysis opens up opportunities to build research synergies between countries, which can improve the quality and quantity of science in the field of STEAM research (Wulan Aulia Azizah & Nur Indah Wahyuni, 2024). These findings are not only useful for academic mapping, but can also be a reference for policy makers in formulating strategies to strengthen competencies in national and global education.

Identifying data with the keyword "STEAM AND Elementary Science Education" is done through co-occurrence analysis through the VOSViewer application. The analysis results show that a total of 401 keywords were identified. The results of co-occurrence analysis based on keywords are presented in Figure 3.

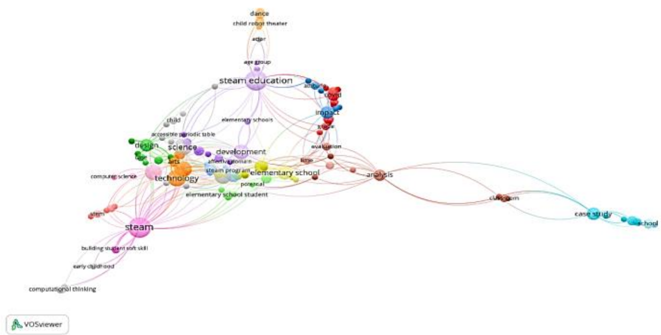

Figure 3. Visualization of Co-occurrence Network with Keyword STEAM and Elementary Science Education
Source: VOSViewer Data Processing

The network with 401 identified STEAM and Elementary Science Education keywords shows several interconnected clusters, reflecting the research focus in this area. The interconnected clusters reflect the various aspects of applying the STEAM approach in elementary school and early childhood education.

The first cluster is dominated by the keywords "STEAM Education", "Elementary School", and "STEAM" relating to the integration of arts and creativity in learning, with keywords such as "Arts", "dance", and "Art". This shows that the integration of arts and creative activities is an important component in the STEAM approach, especially in developing learners' expressive, potential and collaborative skills. The concepts of "child" and "early childhood" also appear, emphasizing that this research is not only limited to primary schools but also includes early childhood education, where arts-based approaches are often used to stimulate holistic development (Liao, 2016). This is supported by several STEAM-related studies where incorporating art into the STEM approach can have a positive effect on cognitive, affective, and psychomotor development, and can reduce learners' stress levels while learning (Perignat & Katz-Buonincontro, 2018, 2019; Sousa & Pilecki, 2013). Science and art complement each other because science uses art to produce its methodology, while art must produce creativity and innovation that helps the development of science (E. Kim et al., 2012).

The integration of science in this network map is also evident as a key component in the STEAM approach, focusing on the design of learning strategies, and the application of science concepts at the primary school level. The keywords "science", "design", "development", "project", and "technology", are central to this cluster, indicating that the research in this group focuses not only on traditional science education, but on how science is creatively designed and taught through the STEAM approach. Science is not taught in isolation, but integrated with technology, engineering, art and math. This can be seen from the connection between "science", "technology", and "design", which shows the importance of project-based or problem-solving approaches in science learning. While the linkage with "elementary school student" emphasizes the adaptation of science materials in accordance with the cognitive level of elementary school children and prepares students for future challenges. This is supported by research that says STEAM education aims to prepare students to work in STEAM career fields, which results in social mobility and financial stability (Bertrand & Namukasa, 2023; Niu & Cheng, 2022).

Then the minimum keyword threshold of 5 was determined and selected, and there were only 14 keywords that met the requirements of being relevant to the research topic focus. The results of the co-occurrence analysis based on the selected keywords can be presented in Figure 4.

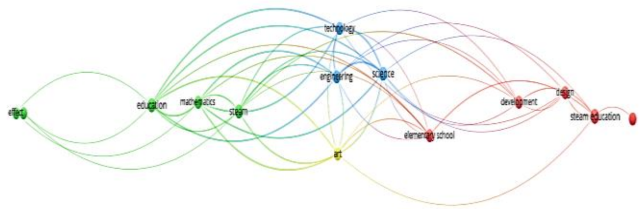

Figure 4. Co-occurrence Network Visualization on Trend STEAM Research in Elementary Science Education
Source: VOSViewer processed data

Based on the results of the co-occurrence network visualization analysis using VOSViewer, it is clear that research on STEAM education forms several interconnected **theme** clusters. This visualization shows that frequently co-occurring terms in STEAM literature are clustered into specific color clusters, each representing a different area of focus.

Green clusters dominate with the main keywords "education", "mathematics" and "STEAM". This indicates that education and mathematics are one of the main foundations in STEAM, where integration between disciplines is an important focus. In addition, the keyword "effect" found in this cluster indicates that many studies highlight the effect or impact of implementing STEAM education on learners.

The blue cluster seen centered on the keywords "technology", "engineering", and "science" shows the close relationship between aspects of technology, engineering, and science. These clusters reinforce the characteristics of the STEAM approach that combines 21st century skills with mastery of technology and problem solving

The keyword "art" appears in yellow clusters, indicating the role of art as a creative bridge in integrating science, technology, engineering and math. Art does not stand alone, but can build strong relationships with other fields to enhance learners' creativity in project-based learning.

Based on co-occurrence analysis using VOSViewer, research on STEAM education is clustered into several interrelated thematic clusters, reflecting the multidisciplinarity and integrity of the STEAM approach. The green cluster dominated by the keywords "education", "mathematics" and "STEAM" indicates that mathematics education is a key foundation in STEAM integration, with a focus on the impact of its implementation on learning (Perignat & Katz-Buonincontro, 2019).

The blue cluster centered on the keywords "technology", "engineering" and "science" emphasizes the characteristics of STEAM as an approach that incorporates 21st century skills, STEM-based problem solving and technological literacy (Herro et al., 2017). The red cluster that includes the keywords "STEAM education", "development", "design", and "elementary school" indicates the focus of research on curriculum development and STEAM learning design at the elementary school level, emphasizing the importance of forming cross-disciplinary competencies early on (Henriksen, 2017).

The yellow cluster with the keyword "art" shows the role of art as a key element that enriches STEM integration through creativity and project-based approaches. This finding is in line with research that art serves as a catalyst in connecting science, technology, engineering and math, while increasing learner engagement (Liao, 2016). Overall, this analysis confirms that STEAM education research is dynamically evolving with a focus on multidisciplinary integration, curriculum development and its impact on learning at different levels of education.

Co-occurrence analysis was further conducted by identifying the research-focused picture through overlay visualization. Through overlay visualization, information on trending issues can be presented. The results of the analysis are presented in Figure 5.

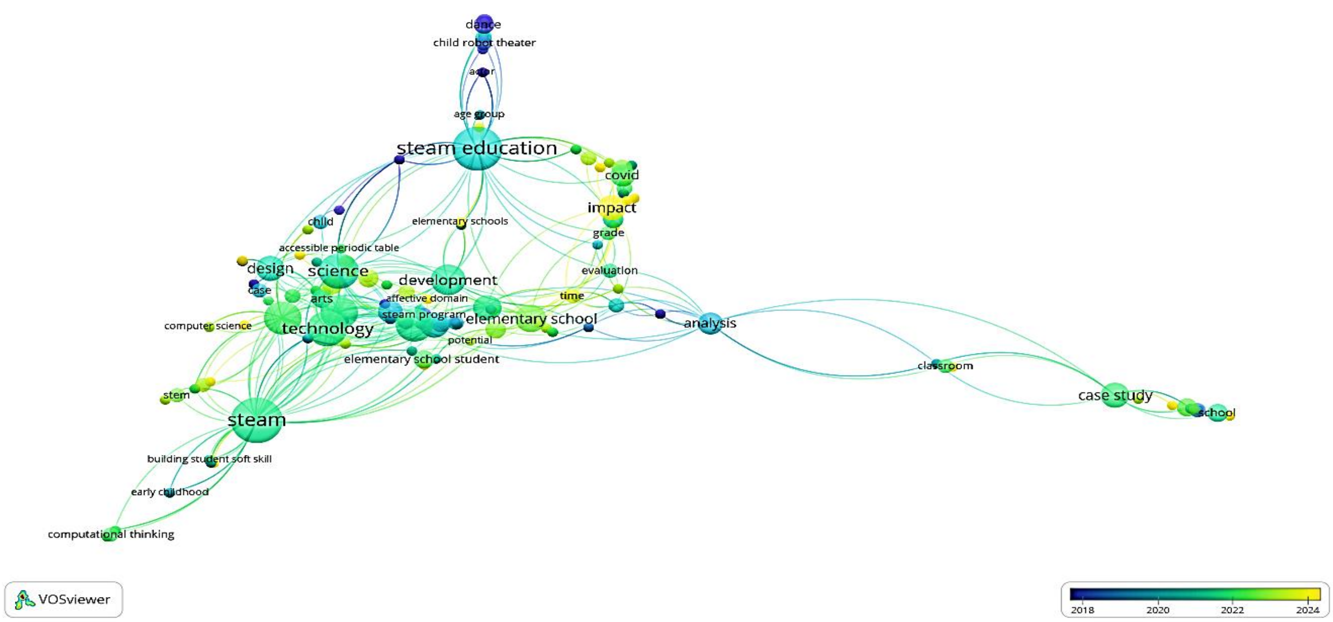

Figure 5. Co-occurrence Overlay Visualization of STEAM Research Trends in Elementary School Science Education
Source: VOSViewer Processed Data

The visualization overlay image generated through VOSViewer shows the development of research trends related to the implementation of the STEAM approach in science education in primary schools from 2018 to 2024. The colors in this visualization indicate the year of publication, where blue indicates older research spanning 2018 to 2019, green for mid-2020 to 2021, and yellow marks the most recent research in 2022 to 2024.

Based on the map, the keywords "STEAM education", "science", "technology", and "elementary school" appear as the largest points showing that STEAM integration, especially in elementary level education, has become a serious concern to encourage science learning innovation. Furthermore, the keywords "impact", "covid", "evaluation" and "grade" appear in yellow, indicating that these topics have become the latest research trends. This shows that since the covid-19 pandemic, there has been an increased interest in evaluating the effectiveness of STEAM learning implementation (Priyantini et al., 2021), including its impact on student learning outcomes.

It can be seen that small clusters with the keywords "dance", "child robot theater", and "arts" indicate a creative approach that incorporates elements of performative arts in the context of STEAM education. This indicates that the arts dimension is starting to be integrated more diversely, not only in the form of visual arts but also in the form of performing arts (Budiyanto et al., 2022). The keywords "case study", "classroom", and "school" that appear in the right area of the map, show the existence of case study-based research methods as the dominant approach in evaluating STEAM implementation practices in real classrooms. In general, this overlay map shows that STEAM research trends in basic education are moving from a focus on model development towards impact analysis, program evaluation, and strengthening the affective and creative dimensions of learners. A summary of STEAM research trends in primary school science education based on visualization overlay analysis can be seen in Table 3.

Table 3. Summary of STEAM Research Trends in Elementary School Science Education

Years	Main Research Focus & Keywords	Description
2018-2019	Development of STEAM concept and Innovative learning model. The Keywords; STEAM education, technology, science, design.	Early research still focuses on the definition and development of STEAM curriculum.
2020-2021	Implementation of STEAM program in elementary school. The keywords; Elementary school, development, steam program.	Many case studies in elementary schools are starting. Adaptation of simple technology in science and math learning.
2022	Evaluation of the effectiveness of STEAM learning and the impact of the Covid-19 pandemic. The keywords; Covid, impact, evaluation, grade.	The focus is shifting to analyzing the impact of online learning and changes in learning methods.
2023	Innovation of arts and technology integration in STEAM education. The keywords; Dance, child robot theater, arts, computational thinking.	Cross-disciplinary approaches are increasingly explored, art has become important to be included in STEM into STEAM.
2024	Case studies of STEAM implementation in various primary school contexts. The keywords; Case study, classroom, school, analysis.	Case-based research (case study) is increasingly dominant to understand local effectiveness as well as continuous evaluation and innovation in the development of STEAM-based learning products.

Conclusion

Based on a bibliometric analysis of the development of STEAM research in elementary science education from 2018 to 2024, this study concludes that there has been a significant evolution in research focus from conceptual approaches toward practical implementation with technology integration. The main findings reveal that digital transformation and technology integration have become the main drivers of STEAM implementation, where arts-based approaches provide significant creative dimensions to science learning.The results demonstrate that STEAM implementation proves effective across various learning conditions, including during the COVID-19 pandemic which served as a catalyst for accelerated research on STEAM effectiveness in emergency education situations. Recent innovations show more comprehensive arts integration through performing arts such as dance and children's robotic theater, along with a methodological shift toward contextual case study approaches that represent the latest methodological trend. Practical implications of these findings emphasize the need for developing integrative curricula that combine arts and technology, continuous teacher training programs, creating learning environments that support student experimentation and innovation, and multidisciplinary collaboration between education, technology, and arts in learning material development. This study recommends the implementation of integrated and contextual STEAM approaches to enhance the quality of elementary science education and equip students with relevant 21st century competencies.

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Author Contributions

Conceptualization, formal analysis by N.A.; writing—original draft preparation, result and discussion, I.A.N and P.B.K.; writing—original draft preparation, result and discussion, methodology, supervision and review N.A.; Supervision, conclusion and review, P.N.

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Conflicts of Interest

For thesis defense requirements.

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