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Uncovering STEAM Research Patterns and Gaps: Systematic Literature Review in Education Journal

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Abstract: This study systematically analyzes trends, patterns, and research gaps in STEAM (Science, Technology, Engineering, Arts, and Mathematics) studies published in the JPPIPA Journal from 2021 to the present. A systematic review of 35 empirical articles reveals that most studies employed a quantitative approach, particularly quasi-experimental methods, to assess STEAM's impact on student learning outcomes. Project-based learning (PjBL) and problem-based learning (PBL) were the dominant instructional models, significantly enhancing critical thinking, problem-solving, communication, and collaboration skills. Some studies integrated local wisdom and technology-based tools such as e-modules, augmented reality (AR), and e-comics to boost engagement. However, limited qualitative research explores students' and teachers' experiences, and few long-term studies assess STEAM's sustained impact. Research remains concentrated on primary and secondary education, with minimal focus on higher or vocational education, crucial for workforce readiness. Additionally, while critical thinking skills have improved, fostering creativity remains a challenge. Future research should incorporate qualitative and mixed-methods approaches, conduct longitudinal studies, and develop reliable STEAM assessment instruments to enhance implementation across diverse educational contexts.

Keywords: Critical thinking; JPPIPA journal; Research GAP; STEAM

Introduction

In recent years, the Science, Technology, Engineering, Arts, and Mathematics (STEAM) approach in education has gained significant attention as an innovative method to enhance learning quality. STEAM education integrates the arts with STEM disciplines to cultivate essential 21st-century skills such as creativity, problem-solving, collaboration, digital literacy, information literacy, and adaptability (Papadopoulou, 2024). These competencies are crucial for preparing students to navigate real-world challenges and meet the demands of an evolving workforce (Li, 2024). According to recent labor market reports, the demand for STEM-related jobs is rapidly increasing, and STEAM education provides a holistic approach to bridging the skills gap in these fields by fostering interdisciplinary learning and innovation (Ertas, 2022).

Along with the growing emphasis on STEAM in education, numerous studies have investigated its effectiveness, implementation strategies, and associated challenges across different educational levels. Research indicates that STEAM-based learning enhances student engagement, fosters active learning, and supports creative problem-solving (Alkhatatneh, 2024). However, despite the increasing volume of research, there remains a lack of systematic reviews that comprehensively analyze trends, dominant findings, and research gaps in this field. A deeper understanding of how STEAM contributes to educational advancements is necessary to inform future policies and instructional practices.

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One of the main challenges in implementing STEAM is the lack of resources and varying student abilities, which can hinder the effectiveness of the approach. However, creative solutions such as using recycled materials for musical instruments and digital applications for music education have been employed to overcome these challenges (Purhanudin, 2025). Teachers often face difficulties in designing STEAM-based curricula that align with educational standards like the Kurikulum Merdeka. Training programs have been developed to help educators design effective STEAM lesson plans (Boice et al., 2021).

One of the primary sources of research on STEAM education is the Jurnal Penelitian Pendidikan IPA (JPPIPA), which is recognized for publishing high-quality studies on innovations and trends in science and technology education. This journal serves as a critical platform for disseminating empirical findings on STEAM implementation, making it an essential resource for understanding its development. Since 2021, 46 relevant articles have been identified in this journal, covering various aspects such as STEAM-based instructional models, their impact on student learning outcomes, and their role in fostering 21st-century skills.

Despite the growing body of literature, no systematic review has holistically examined STEAM research trends, methodological patterns, and research gaps within this journal. Therefore, this study aims to conduct a systematic literature review (SLR) of 35 articles published in the Journal of Science Education Research from 2021 to the present. The review will analyze key research patterns, dominant findings, and areas requiring further investigation. By synthesizing existing literature, this study seeks to provide a comprehensive overview of STEAM research directions and offer valuable recommendations for researchers and educators to enhance future studies and practical implementations of STEAM education.

Method

This research applies the Systematic Literature Review (SLR) method with an approach based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) model as outlined by (Page et al., 2021). The steps in this study are as follows:

Data Identification and Collection

Search Strategy: Articles were collected from Science Education Research Journal from 2021 to the present using predefined search keywords: 'STEAM education,' 'STEM and arts integration,' 'STEAM pedagogy,' 'STEAM curriculum,' and 'STEAM learning outcomes' 46 articles were obtained.

Inclusion Criteria: Selected articles met the following conditions: (a) Empirical research studies, case studies, and experimental research related to STEAM in education; (b) Articles available in full text and published in peer-reviewed journals; (c) Articles written in English.

Exclusion Criteria: The following articles were excluded: (a) Theoretical reviews, conference papers, and opinion-based articles (8 Article); (b) Studies unrelated to STEAM education (3 article).

Handling of Duplicate Articles: Duplicates were identified using reference management software (Zotero) and removed before the screening process. After all the stages were carried out, 35 articles were found eligible for further analysis.

Article Screening

First Stage (Abstract and Keyword Screening): Articles were initially screened based on their title, abstract, and keywords to assess relevance to STEAM education. Second Stage (Full-Text Review): Articles passing the first stage were reviewed in full to ensure they aligned with the study criteria. Resolution of Discrepancies: If disagreements arose regarding the inclusion of an article, discussions among researchers were conducted until a consensus was reached. Screening Flow: The number of articles at each stage was recorded and presented in a PRISMA flowchart for transparency.

Data Extraction and Analysis

Data Coding Categories: (a) Study objectives (e.g., improving STEAM integration, measuring learning outcomes). (b) Research methods (e.g., qualitative, quantitative, mixed methods). (c) Sample characteristics (e.g., student age, education level, study location). (d) Main findings (e.g., STEAM teaching effectiveness, implementation challenges).

Thematic Analysis: (a) An inductive approach was used to identify emerging themes from the collected data (Braun & Clarke, 2006). (b) Key trends, recurring concepts, and research gaps were categorized.

VOSviewer Analysis: (a) The VOSviewer software was used to visualize keyword relationships, co-citation networks, and research clusters. (b) Parameters such as keyword frequency, co-occurrence networks, and thematic clusters were considered.

Analysis with VOSviewer

Keyword Mapping: This study uses co-occurrence networks to visualise how different keywords relate to each other. In this network, nodes represent unique words, while edges indicate the frequency of their co-occurrence in the data set. This helps in understanding the interconnectedness of different terms related to a crisis situation (Bukar et al., 2025).

Thematic Visualization: Dominant themes and emerging trends were identified to show how research areas in STEAM education are evolving. Thematic visualisations provide dynamic insights into the nature of the evolving crisis situation (Bukar et al., 2025).

Impact Assessment: The network analysis helped identify influential studies and research gaps in the field. Visualised data enables a more nuanced understanding of public sentiment and immediate needs, allowing respondents to prioritise actions based on real-time information (Bukar et al., 2025).

VOSViewer is particularly effective for the analysis of citation and bibliographic coupling, enabling clear network visualisation that makes complex relationships easier to interpret (Ni & Abdullah, 2025).

Synthesis of Results

Integration of Findings: (a) The thematic analysis results were combined with VOSviewer visualizations to provide a comprehensive overview of STEAM research trends. (b) Identified research gaps were highlighted to suggest future study directions. Quality Consideration: The credibility of the reviewed studies was assessed based on journal impact factors, citation counts, and methodological rigor. Presentation of Results: (a) Findings were summarized in tables and visual diagrams for clarity. (b) A structured synthesis was provided to highlight key contributions to STEAM education research.

Flowchart Representation

A detailed PRISMA-based flowchart will be included to visually represent the research process, from identification to synthesis. The method was adapted from trusted sources, including the PRISMA guide to *Systematic Literature Review* and research methodology guidelines in education published by leading academics (Snyder, 2019). By using a systematic and transparent approach, this study is expected to make a significant contribution understanding the development of STEAM research in education.

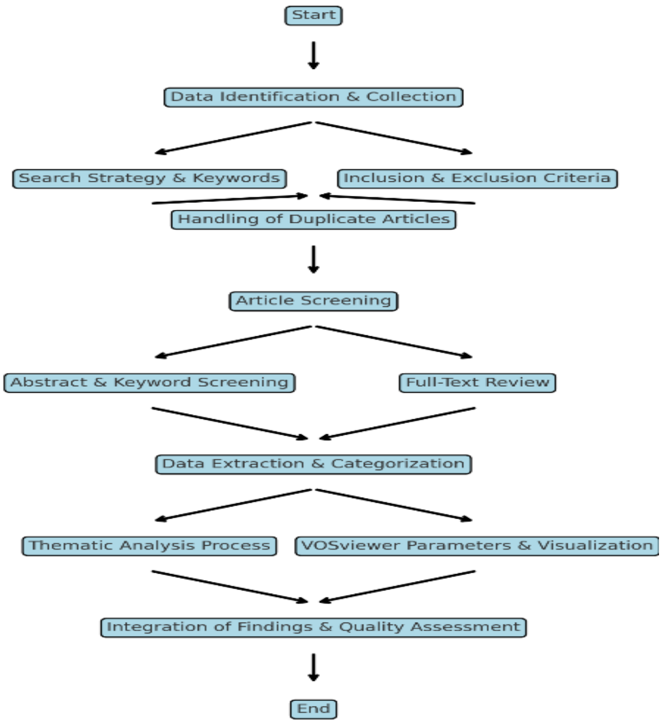

Figure 1. Flowchart Research method with PRISMA

Result and Discussion

Based on the data analysis using VOSviewer, several key findings were obtained:

Dominant Keywords in STEAM Research

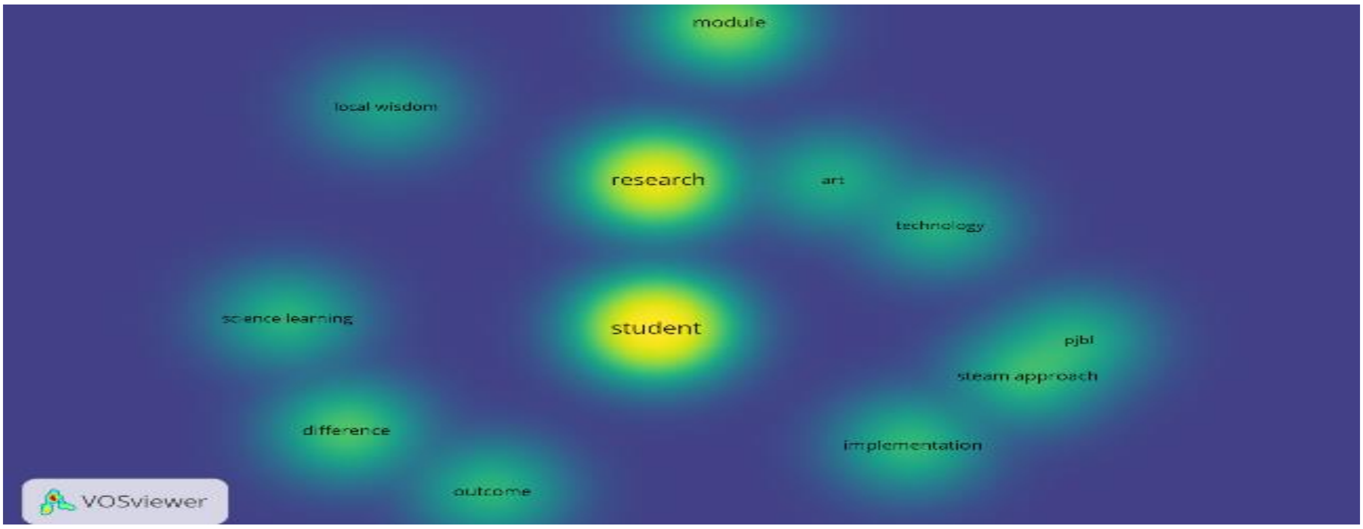

Figure 2. Visualization of density using VosViewer application

The keywords with the highest occurrence are student (90 times), research (66 times), and module (31 times), indicating that STEAM research focuses heavily on learners, research methods, and learning modules.

Topics with Strong Connections

Science learning has a total link strength of 250, indicating that this topic is often associated with other STEAM concepts in research. Science learning also plays a crucial role in developing scientific literacy and character. By engaging students in scientific inquiry, educators can foster critical thinking, creativity, and positive attitudes, which are essential for personal and academic growth (Rubini et al., 2018).

Implementation and technology also have strong connections with various other topics, signaling that STEAM studies highlight the implementation and use of technology.

Publication Trends by Year

The average year of publication for the various keywords ranges from 2023 to 2023.8, indicating that research on STEAM is still growing rapidly in a very recent timeframe.

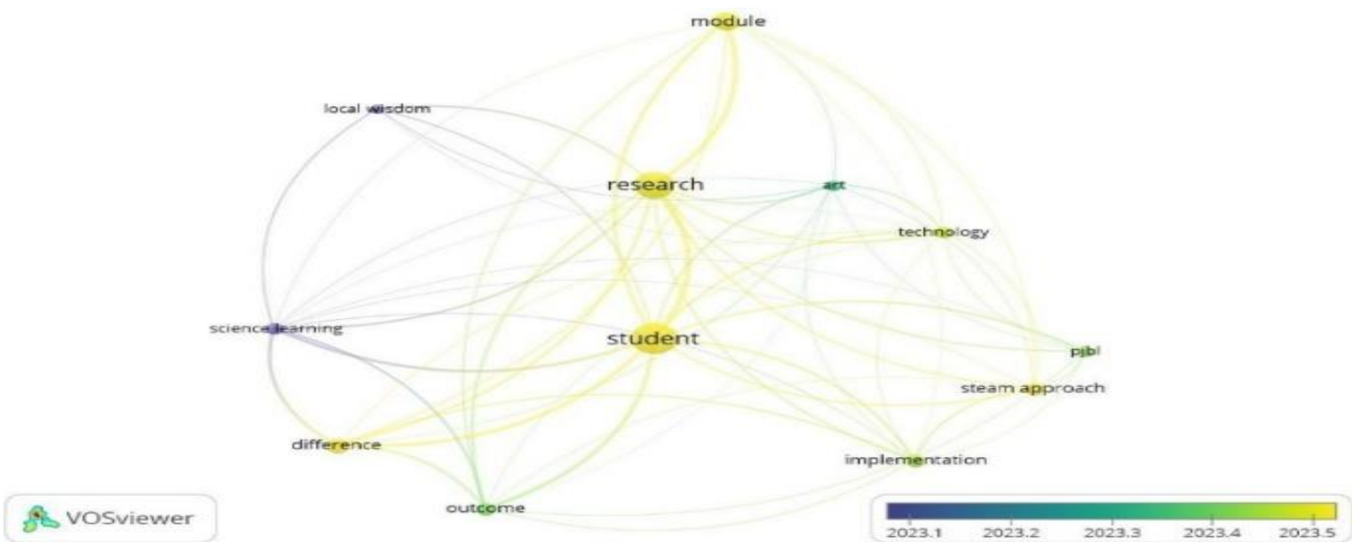

Figure 3. Visualisation of occurrence by year using VosViewer application

Research Cluster Mapping

Based on the Figure 4, there are four main clusters: Cluster 1: Focuses on students, science learning and outcomes, which highlights the impact of STEAM on learning. Cluster 2: Contains implementation, steam approach, and PjBL (Project- Based Learning), which emphasize STEAM-based learning methods and strategies. Cluster 3: Includes art, local wisdom and technology, which shows the relevance of STEAM to art and local wisdom. Cluster 4: Include research and modules, which highlight the methodological aspects of STEAM studies.

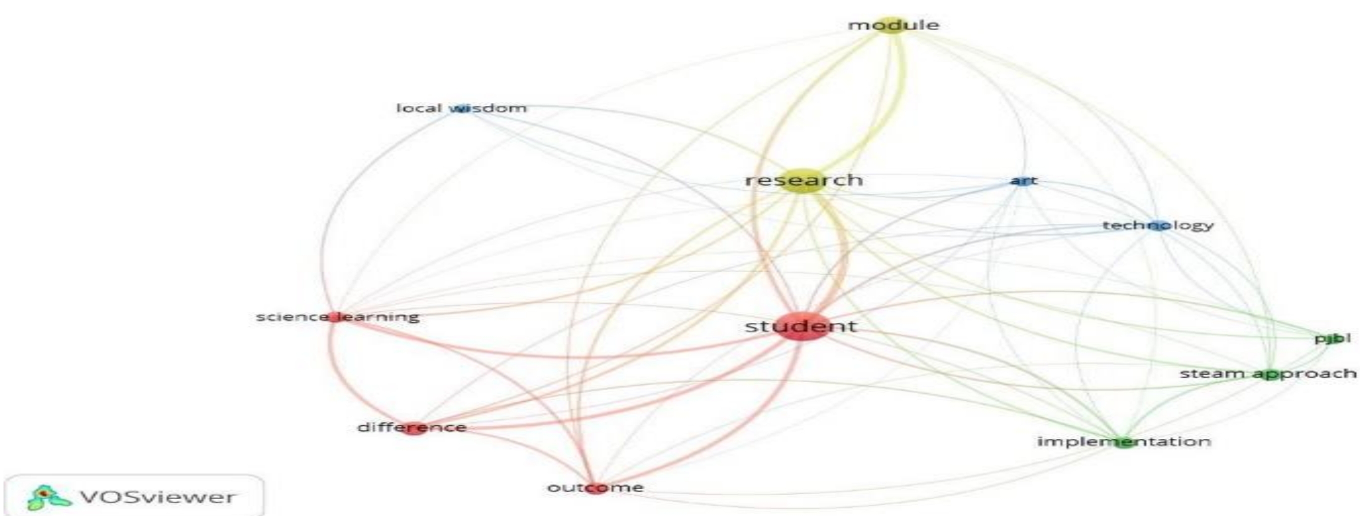

Figure 4. Network visualisation using VosViewer application

By looking at the supporting data from Vosviewer, we can do more analysis on this research, research on STEAM (Science, Technology, Engineering, Arts, and Mathematics) in the journal JPPIPA (Journal of Science Education Research) indexed by SINTA 2 has only started since 2022. This is because STEAM itself is still being developed by adding Art to the previous approach, namely STEM. The addition of Art to the traditional STEM framework recognizes the importance of creativity and design in scientific and technological fields. This integration encourages students to think critically and innovatively, improving their problem-solving skills (Fanani et al., 2025). Based on research methods from year to year, the following data is obtained:

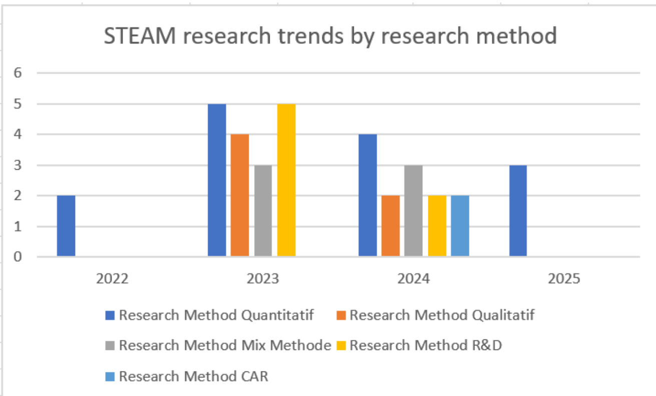

Figure 5. STEAM research trends by research method

Based on the bar chart showing STEAM research trends by research method from 2022 to 2025, it can be seen that quantitative research methods dominate each year. The peak use of this method occurred in 2023, where the number of studies using quantitative approaches reached the highest number compared to other methods. In addition, 2023 also shows a high diversity of methods, with a relatively balanced number of studies using qualitative, mix-method, R&D, and classroom action research (CAR) approaches. However, in 2024, although quantitative methods remained the most dominant, there was a slight increase in qualitative and mix-method methods compared to previous years.

In the use of quantitative methods, some studies apply experimental designs such as quasi-experimental and pre-experimental. Quasi-experimental designs are commonly used in studies that compare the effectiveness of STEAM implementation in experimental and control groups without strict randomisation of subjects. For example, some studies apply the Nonequivalent Control Group design, where one group is given STEAM-based treatment while the other group follows conventional learning, then the students' learning outcomes or skills are analysed using certain statistical tests (Creswell, 2013). According to Choirunnisa et al. (2023), the main objective of this study was to determine the effectiveness of project-based STEAM learning in improving science literacy skills among students. Quasi-experimental methods are suitable for evaluating such educational interventions, as they can provide insight into the impact of specific teaching methods on student outcomes. Meanwhile, pre-experimental designs such as One-Group Pretest-Posttest are also widely used in studies that want to see the impact of STEAM implementation on one group of learners before and after the intervention (McKenney & Reeves, 2012). According to Sakdiah et al. (2022), the Pretest-Posttest One Group Design was chosen because it allows researchers to measure the effect of an intervention (in this case, STEAM learning) on one group of participants by comparing their performance before and after treatment. This design is particularly useful when a control group is not feasible or available. However, the lack of a control group in this design is often a limitation in generalising the research results.

Over time, this trend pattern appears to be shifting. The year 2025 shows a tendency for STEAM research to favour the use of quantitative methods and classroom action research, while other methods such as R&D and mixed-methods have decreased or are not used. The decline in R&D methods indicates that development-based research is more prevalent in the early phase of the STEAM trend, especially in 2023, while subsequent years focus more on application and evaluation. However, there is still the possibility of R&D and CAR research being conducted. The authors chose the Development method (R&D) to ensure a structured, expert-informed, iterative approach to creating high-quality educational media that meets the needs of learners and educators (Mulder et al., 2023). According to Setianingrum et al. (2023), the main objective is to develop a science e-book that incorporates the wisdom of local gamelan based on the STEAM-POE approach. This integration is intended to improve students' understanding of the relationship between science, technology, art, maths and local culture, thus making learning more contextual and meaningful.

The CAR method provided a structured framework for the authors to implement their intervention in phases-planning, action, observation and reflection. This systematic approach is essential for assessing the impact of STEAM pedagogy on children's scientific literacy (Habibi, 2023). This research emphasises the importance of adapting teaching methods to meet the diverse needs of students. By using action research, the authors were able to gather real-time feedback from students, allowing them to make the necessary adjustments to the learning media and methods being applied (Mulder et al., 2023). The integration of STEAM in digital learning environments has been effective in enhancing numeracy literacy among elementary students. This approach combines experimental and quantitative methods to improve learning outcomes (Hidayanthi et al., 2024).

If this trend continues, future STEAM research is likely to be dominated by quantitative methods and classroom action research, with an emphasis on measuring impact and implementation in an educational context. This shift suggests that after a fairly robust STEAM model development phase in 2023, the focus of research is shifting to evaluating the effectiveness of its application in various learning environments.

Meanwhile, in looking at the distribution of objective studies on Science, Technology, Engineering, Arts, and Mathematics (STEAM) in the Journal of Science Education Research Journal (JPPIPA) as the following graph:

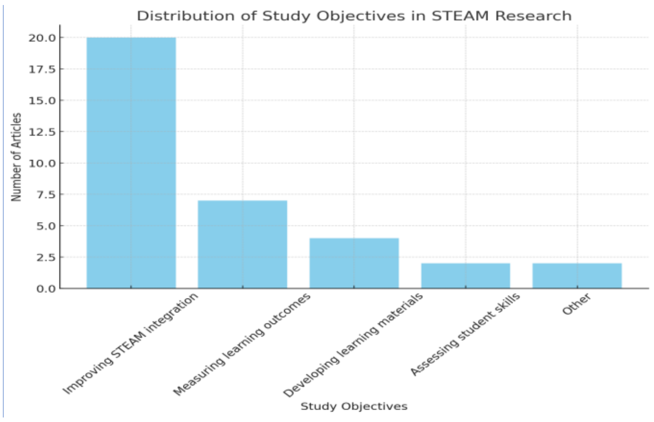

Figure 6. Distribution of study objectives in STEAM research

Based on the graph, STEAM research in Indonesia shows a primary focus on several research objectives that can be categorized into four broad groups. The integration of STEAM in learning is the most dominant research objective, indicating that there are still challenges in implementing this approach effectively at various levels of education (Atika et al., 2023). Many studies explored learning strategies and models that can optimize STEAM in the school curriculum. In addition, the evaluation of learner learning outcomes is also a major concern, with research focusing on how the STEAM approach can improve students' critical thinking, problem-solving and creativity skills (Alvendri et al., 2024).

In addition, research has also been conducted in the development of STEAM-based teaching materials, such as modules, interactive media, and technology-based learning resources. This shows the need for resources that support the wider implementation of STEAM in schools. According to Rusni et al. (2023), the developed e-modules can significantly improve students' critical thinking skills as well as demonstrate the effectiveness of such resources in encouraging higher-order thinking. The development of Steam-based teaching materials, including modules and interactive media, is essential to enhance learning experiences and promote the integration of science, technology, engineering, arts and math in educational settings. This is in line with the observed need for resources that facilitate wider implementation of STEAM in schools (Kohohon et al., 2023). Meanwhile, according to Nuraini et al. (2023), there is a need for resources that support the implementation of STEAM in schools, including the development of modules, interactive media, and technology-based learning resources that can facilitate a more dynamic learning environment.

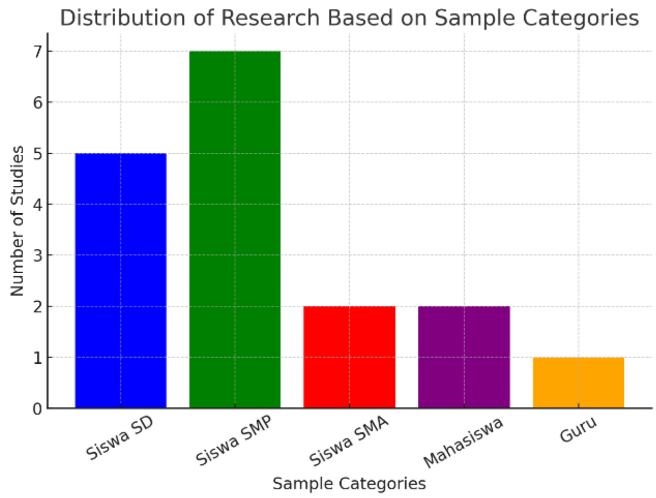

Figure 7. Distribution of research based on sample categories

The figure shows the distribution of research based on the sample category used in studies related to the STEAM approach. From the bar chart, it can be seen that the most research conducted involved junior high school students with 7 studies, followed by elementary school students with 5 studies. Meanwhile, there are only 2 studies each on high school students and university students, and the least is teachers with 1 study. This data indicates that the application of the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach in research is more focused on the primary and junior secondary education levels. This could be due to several factors, such as the suitability of the curriculum, the need for learning innovation at the primary and secondary levels, and the drive to improve critical and creative thinking skills early on.

Many high school students may struggle with collaboration and engagement due to traditional teacher-centred learning methods. The STEAM approach offers a more interactive and student-centred learning environment, which can help address this gap and improve overall educational outcomes. According to Andup et al. (2025), Implementing the STEAM approach can lead to improved educational standards by fostering a more comprehensive and contextualised learning environment which is crucial in preparing students for future challenges in their careers and personal lives.

At the student level, this research recognizes that students have varied cognitive abilities and learning styles. By focusing on the STEAM approach, this module aims to provide a more inclusive educational experience that can accommodate these differences (Rozi et al., 2024). The STEAM approach is designed to develop critical skills necessary for the 21st century, such as creativity, critical thinking, collaboration, and communication (often referred to as the 4C skills). These skills are essential for students to succeed in a rapidly changing world(Alhayat et al., 2024). At the elementary level, the STEAM-based project learning model has been shown to significantly improve student learning outcomes, particularly in project-based activities and literacy. This is evidenced by higher N-Gain scores in experimental groups compared to control groups (Rostikawati et al., 2024).

If Steam is combined with a learning model such as PjBL, it will have a better impact in shaping the character of students. In Zayyinah et al. (2022), STEAM-PjBL is able to increase the ability to communicate and share ideas effectively, the ability to work productively and responsibly, the ability to adapt and respect the contributions of others so that collaboration in learning goes well. PJBL-Steam encourages students to actively engage in solving real-world problems. This hands-on approach helps them develop critical thinking skills as they analyse situations, evaluate options and make evidence-based decisions, students are given the freedom to plan their learning activities and projects allows them to explore different solutions and innovate, which is important for developing creative thinking skills (Salhuteru et al., 2025).

In addition to PjBL, the Problem-Based Learning (PBL) model is also often combined with STEAM. This combination is expected to sharpen students' ability to think critically. This critical thinking ability can help students solve problems they encounter in everyday life. According to Kohohon et al. (2023), the PBL model encourages students to engage deeply with the material. By solving real-world problems, students are asked to interpret information thoroughly, which enhances their ability to think critically about various concepts. Project-Based Learning (PjBL) and Problem-Based Learning (PBL) are highlighted as effective models for increasing student engagement and learning outcomes. PjBL encourages active participation and curiosity, reducing boredom and enhancing learning experiences (Haryanti et al., 2024). Online learning platforms have also adopted the STEAM model to create engaging and effective learning experiences. This model helps develop critical thinking, analytical skills, and creativity among students (Sa'ida, 2021).

The results of the article analysis show several gaps in the STEAM research that has been conducted. One of the main gaps is the lack of qualitative research that explores the perceptions and experiences of teachers and students in implementing STEAM. Most research still focuses on quantitative approaches, while qualitative studies can provide a deeper understanding of the factors that influence the effectiveness of STEAM in learning practices. With qualitative research, aspects such as the challenges faced by teachers, student motivation, and the dynamics of STEAM implementation in various educational contexts can be more comprehensively understood.

In addition, long-term evaluation of STEAM implementation is limited. Most studies highlight short-term impacts, such as improved learning outcomes within a certain period, without examining how STEAM-based learning affects learners' skill development over a longer period of time. Studies that evaluate the long-term sustainability and effectiveness of STEAM are needed to find out whether this method really has a significant impact on 21st century skills, such as problem solving, collaboration and creativity.

Another gap is evident in the distribution of research that tends to focus more on science and technology subjects, while the implementation of STEAM in the arts and humanities is rarely explored. In fact, the STEAM approach aims to integrate various disciplines holistically, so more research needs to highlight how this method can be effectively applied in non-STEM subjects, such as arts, literature and social sciences.

Finally, there are limitations in the scope of the research sample, most of which are still focused on primary and junior secondary education levels. Meanwhile, the implementation of STEAM in higher education and vocational education is still not widely discussed in existing research. Given the importance of STEAM in preparing students to face the challenges of the world of work and industry, more studies are needed that examine how this approach can be effectively implemented at higher education levels. By addressing these gaps, future STEAM research can be more comprehensive and able to make a wider contribution to education.

With these findings, the research can provide insights into STEAM trends and the potential for further development.

Conclusion

Highlighting key findings: The analysis reveals that most STEAM research in JPPIPA adopts a quantitative approach, particularly quasi-experimental designs. This dominance indicates a primary focus on evaluating the effectiveness of STEAM implementation on student learning outcomes statistically. However, this approach has limitations in exploring students' learning experiences in depth. Project-Based Learning (PjBL) and Problem-Based Learning (PBL) are the most frequently used instructional models and have proven effective in enhancing students' critical thinking, problem-solving, communication, and collaboration skills. The success of these models implies that active learning approaches that position students at the center of the learning process align well with the goals of STEAM to foster 21st-century competencies. The integration of local cultural elements in STEAM learning also shows positive impacts by increasing the contextual relevance of learning. When content is aligned with local contexts, students can better relate to the material, which enhances their motivation to learn. On the other hand, the use of technologies such as e-modules, augmented reality (AR), and STEAM-based e-comics has proven effective in increasing student engagement through interactive, visual, and immersive content delivery that suits the characteristics of digital-native learners. Emphasizing research gaps: The lack of qualitative research is a key gap that must be addressed. Qualitative studies are crucial for exploring the perceptions, experiences, and challenges of teachers and students in implementing the STEAM approach. Without these studies, our understanding of non-technical factors influencing the success of STEAM implementation remains limited. Long-term evaluations of STEAM implementation are also scarce. Most studies only assess short-term impacts, such as improved learning outcomes within a single learning cycle. Longitudinal studies are essential to evaluate the sustained effects of STEAM learning on the development of 21st-century skills, especially creativity and innovation. Moreover, research has mostly focused on primary and lower secondary education, creating a gap in knowledge regarding STEAM's effectiveness in higher and vocational education. These levels are critical for preparing students for real-world challenges and workforce readiness, where transdisciplinary thinking, innovation, and adaptability are crucial. More concrete recommendations: Conduct qualitative studies such as classroom observations, in-depth interviews, and case studies to explore teachers' and students' experiences and challenges in STEAM implementation. Implement longitudinal research to evaluate the long-term impact of STEAM on the development of students' critical thinking, collaboration, and creativity skills. Develop valid and reliable STEAM assessment instruments to measure higher-order thinking skills (HOTS), creativity, and collaboration. Promote interdisciplinary collaboration between science, technology, arts, and education professionals in designing and implementing STEAM education. Adopt instructional strategies that foster student creativity, such as design thinking, inquiry-based learning, and open-ended problem-solving based on real-world contexts. Based on the analysis of STEAM research in the JPPIPA journal, it is evident that quantitative approaches, particularly quasi-experimental methods, dominate the field, focusing on evaluating the effects of STEAM implementation on student learning outcomes. Project-Based Learning (PjBL) and Problem-Based Learning (PBL) are widely applied and have proven effective in developing students' critical thinking, problem-solving, collaboration, and communication skills. The integration of local culture enhances the contextual relevance of learning, while the use of technology, such as e-modules, AR, and e-comics, significantly boosts student engagement. However, a notable lack of qualitative studies limits our understanding of teachers' and students' in-depth experiences, and the absence of long-term evaluations hinders insights into the sustained impact of STEAM. Furthermore, limited research in higher and vocational education restricts the development of contextually appropriate STEAM models for workforce preparation. Therefore, it is recommended to broaden the research scope, increase qualitative and longitudinal studies, and develop effective strategies to support student creativity and accurate assessments to ensure a more sustainable and comprehensive implementation of STEAM.

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Author Contributions

Conceptualization, N., H.; methodology, N.; validation, H.; formal analysis, N.; investigation, N.; resources, N.; data curation, N.; writing—original draft preparation, N.; writing—review and editing, N.; visualization, N. and H. 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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