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STEAM in Elementary School

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Abstract. 21st century education demands critical, creative, collaborative, and digital literacy skills. The STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach is an innovation that integrates various disciplines contextually to create meaningful learning. This study aims to analyze the application of STEAM in elementary schools by reviewing the supporting factors, constraints, and their impact on student learning processes and outcomes. The method used is a qualitative approach with library research, through the analysis of various research results, educational theories, and relevant policies. Data were obtained from secondary literature such as scientific journals, books, research reports, and purposively selected policy documents. Thematic content analysis was used to identify key themes such as teacher roles, facilities, policy support, and the impact of STEAM on learning outcomes. The results of the study show that the application of STEAM is efficacious in improving 21st century skills, including critical thinking, creativity, collaboration, and learning motivation. Project-based learning is the most effective strategy in integrating the five disciplines. However, the main obstacles include limited teacher competence, facilities, and policy support. Overall, STEAM has the potential to build creative and future-oriented basic education, noting the need for teacher training, adequate facilities, and interdisciplinary curriculum policies

Keywords: STEAM, Elementary School, 21st Century Skills.

INTRODUCTION

In the last two decades, the world of education has undergone a shift in focus from just content mastery to 21st century competency development: critical thinking, creativity, collaboration, and digital literacy (Hasibuan et al., 2024; Ismuni et al., 2024; Rodrigues et al., 2024). The concept of STEAM (Science, Technology, Engineering, Arts, and Mathematics) emerged as one of the answers to these demands, because it combines elements of science, technology, engineering, mathematics with aspects of art (Arts) so that learning becomes more complete and contextual. Research and education initiatives in many countries have shown that institutions, private institutions, and industry are increasingly paying attention to the integration of STEAM in the curriculum, with a projection that the global STEAM education market will reach USD 52.74 billion by 2034, growing at around 10.10% (CAGR) from 2025 to 2034 (Zoting, 2025).

At the primary education level, the adoption of STEAM becomes very strategic because at this age the cognitive, affective, and psychomotor foundations of students are being formed. STEAM learning in elementary school has the potential to change the way students see interdisciplinary relationships no longer stand-alone "Science, Mathematics, Arts", but as a network of synergies in solving real problems. For example, a study of the digital STEAM-Inquiry found that there were significant differences in students' mathematical literacy when using STEAM modules compared to conventional methods (Audiana & Rusnilawati, 2024; Wahyuni & Rusnilawati, 2024). In Indonesia itself, research on STEAM applications at the elementary school level is beginning to emerge, especially in the application of the model project-based learning integrated to improve students' science literacy(Choirunnisa et al., 2023; Susanta et al., 2025a).

Although ideally STEAM bridges disciplines to enrich each other, in practice various problems hinder its application in elementary schools. First, some teachers have not received specific technical or pedagogical training to integrate aspects of technology, engineering, and art into their teaching (especially in primary schools). A survey in elementary schools in West Java showed that although teachers stated that they had tried activities that supported STEAM, obstacles in facilities (including technological tools) and technical support were the main obstacles (Malagola, 2023). Second, resources (e.g. mini-labs, manipulative materials, simple software) are not evenly available in primary schools, especially in remote areas or areas with limited education budgets (Lili Suharningsih & Achmad Fathoni, 2025; Yanto et al., 2025). Third, although there is already STEAM research in Indonesia, many studies are still separate (studies on one discipline or one module only), so they have not yet formed an operational and systematic integrative framework (Kartikaningtyas et al., 2025; Nugraha et al., 2023; Putri Nabila, 2025). In a systematic review of STEM/STEAM research in Indonesia (2016–2021), many studies still focus on learning strategies, media, and teaching materials, while aspects of teacher perception, evaluation/assessment, or cross-disciplinary integration are relatively under-appreciated (Without et al., 2023).

This gap (between the ideal of STEAM and primary school practice) drives the need for more in-depth research: how to design feasible and effective STEAM learning models in elementary schools, taking into account the local context (facilities, teacher capabilities, student character). The primary purpose of this article is to examine (a) the Implementation of STEAM in Elementary Schools, (b) The Impact of STEAM on Student Learning Processes and Outcomes, and (c) Implementation Obstacles and Challenges. Through empirical and conceptual studies, this article hopes to fill the gap in operational research in Indonesia while building a framework for the implementation of STEAM Elementary that can be replicated and adjusted.

Theoretically, this article is expected to contribute to the conceptual framework of STEAM in the context of elementary schools (both Indonesian and similar countries), by clarifying contextual variables (schools, teachers, resources) and cross-disciplinary integration mechanisms. Practically, the results of this research are expected to be the basis for recommendations for policy makers (Ministry of Education and Culture, education offices), curriculum makers, and school practitioners in designing teacher training, facility funding, and STEAM learning modules for elementary schools. Thus, this research aims to strengthen the foundation of education that is relevant to the needs of the 21st century from the earliest level of education.

METHODOLOGY

This research uses a qualitative approach with the library research method, (Moleong, 2018; Wicaksana & Rachman, 2018). The primary focus of this research is to examine, interpret, and synthesize various previous research results, educational theories, and policies related to the application of the STEAM approach in elementary schools. This approach was chosen because it can provide a deep understanding of various perspectives and findings that already exist, so that it can form a strong conceptual basis for further analysis.

The data sources in this study come from various relevant secondary literature, including scientific journal articles, academic books, research report results, conference proceedings, and education policy documents from official institutions. All of these sources were purposively selected based on their relevance to the topic of STEAM and the context of basic education in Indonesia. Data analysis was carried out using thematic content analysis techniques. In this stage, each source of literature is read and examined in depth to find recurring and significant key ideas. The main themes that emerged were then identified and grouped into broad categories, such as the role of teachers, the availability of facilities, policy support, and the impact of STEAM learning on student learning outcomes. This process aims to find patterns, similarities, and differences between research findings, resulting in a narrative synthesis that connects theory with practice in the field.

The validity and reliability of findings are maintained through the transparency of the literature selection process and the application of source triangulation, namely by comparing the results of various studies that have different contexts, methods, and findings. Through this

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step, it is hoped that a comprehensive and credible picture of the implementation of STEAM at the elementary school level will be obtained, including the key factors that determine its success. With this literature study approach, the researcher not only builds a solid theoretical foundation, but also produces practical recommendations for teachers, policymakers, and educational institutions in developing effective, innovative, and contextual STEAM learning models according to the characteristics of basic education in Indonesia.

RESULTS AND DISCUSSION

Implementation of STEAM in Elementary Schools

Analysis of various studies on the implementation of the STEAM (Science, Technology, Engineering, Arts, Mathematics) approach in primary schools shows a consistent pattern in terms of the potential and challenges of its application in the context of primary education. In general, this approach increases students' collaboration, creativity, and critical thinking skills, but also requires teacher readiness, curriculum support, and adequate infrastructure.

Research by Mustoip shows that the implementation of the STEAM learning method significantly develops the collaborative and creative character of elementary school students (Mustoip et al., 2024). These results are in line with a literature review by Erawan et al, which confirmed that STEAM can increase learning motivation and problem-solving skills. However, its implementation is still constrained by the lack of teacher training and effective cross-disciplinary integration (Erawan et al., 2025).

On the other hand, a comparative study by Duong et al. (2024) identify that factors such as teachers' pedagogical competence, policy support, and school culture have a significant influence on the success of STEAM implementation. These findings indicate that the social and structural context of a country also determines the effectiveness of the STEAM approach at the elementary school level. For example, schools in Vietnam that have continuous professional development programs show better results than schools in other countries that do not have similar policies.

Cross-country study by Voicu et al. (2023) underlined the variation in the implementation of STEAM in six European countries, with a focus on teacher readiness and the availability of learning resources. Although the contexts are different, these results are relevant to conditions in Indonesia where teachers often face difficulties in designing integrative activities between science and art. Meanwhile, systematic research by Amanova et al. (2025) reinforcing the findings that the implementation of STEAM globally has a positive impact on academic achievement and 21st century skills development.

Methodologically, most of the research uses a qualitative approach with classroom observations and teacher interviews, which allows for an in-depth understanding of the implementation process. However, the limitation is the lack of longitudinal data that can show a long-term impact on student learning outcomes. Design-based research as conducted by Li et al. (2022) Offer a collaborative learning model between teachers as a potential solution to overcome implementation barriers.

Critically, the main commonality between the studies is the recognition of the value of STEAM in fostering students' creative and collaborative skills. At the same time, the differences lie in the social context, educational policies, and resource readiness. The implications of these findings emphasize the importance of teacher professional development and systemic support so that STEAM is not simply a pedagogical trend, but an integral part of the primary school curriculum oriented towards cross-disciplinary learning.

The Impact of STEAM on Student Learning Processes and Outcomes

The STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach has a profound influence on the development of critical thinking skills, problem-solving, creativity, and learning motivation of elementary school students. Cross-research studies show that

STEAM-based learning models not only improve cognitive learning outcomes, but also shape scientific thinking dispositions and positive attitudes towards the learning process itself.

Research by Quigley et al. (2020) found that the integration of STEAM in learning encourages students to engage in project-based problem-solving activities that demand cross-disciplinary analysis and synthesis of ideas. In this context, students learn to connect science concepts with creative aspects such as design or art, which trigger critical thinking skills naturally. This exploration process makes learning more meaningful because students experience firsthand the relationship between theory and practice.

Similar results were shown by Amanova et al. (2025), which in its systematic review found that STEAM learning improves higher-level thinking skills (higher-order thinking skills) and students' creativity at various levels of education. They concluded that this approach is practical because it engages students in a cycle of design thinking—defining problems, developing ideas, prototyping, and reflecting on outcomes that consistently fosters complex problem-solving skills.

The aspect of learning motivation has also increased significantly. Mustoip et al (2024) report that the implementation of collaborative project-based STEAM increases students' emotional engagement with learning. Students show higher enthusiasm because they feel they have an active role in learning activities, not just recipients of information. These findings are reinforced by a learning design study by Lie et al. (2022), which found that student-to-student cooperation in a STEAM environment strengthens confidence and intrinsic motivation as each individual contributes according to his or her interests and talents.

However, cross-border research by Duong et al (2024) shows that these positive impacts are highly dependent on contextual factors, such as teachers' pedagogical competence, access to laboratory facilities, and education policy support. Schools with ongoing teacher training and adequate learning resources show higher improvements in students' critical thinking skills and motivation than schools that do not have similar structural support.

Methodologically, the majority of studies use quasi-experimental and mixed-methods approaches, allowing researchers to measure changes in learning outcomes while understanding the dynamics of the learning process. However, some studies have limitations in the relatively short observation period so the long-term impact on creativity and motivation has not been fully measured.

Critically, the main commonality between the studies is the recognition that STEAM acts as a catalyst for 21st century skills of critical thinking, collaboration, communication, and creativity. At the same time, the differences lie in the context of implementation and the level of resource readiness. The implication is that the success of the STEAM approach is not solely determined by the curriculum, but by the ability of teachers to design integrative and contextual learning experiences.

Implementation Obstacles and Challenges

Analysis of various studies on the constraints and challenges of implementing the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach in primary schools shows that, although this approach is recognized to be effective in improving 21st-century skills, its application in the field often faces structural, pedagogical, and cultural obstacles.

Research by Erawan et al. (2025) emphasized that the main challenge in the implementation of STEAM in Indonesian elementary schools lies in the readiness of teachers. Many teachers do not yet have the conceptual understanding and practical skills to integrate all five areas into meaningful learning. This is due to the limitations of professional training and the lack of contextual STEAM learning models. Teachers often still focus on conventional approaches based on memorization rather than cross-disciplinary exploration.

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Cross-border study by Duong et al (2024)suggests that barriers to STEAM implementation are also related to the lack of policy support and educational resources. Schools that do not have laboratory facilities, technological equipment, and integrative teaching materials tend to fail to achieve the goals of STEAM to the fullest. This structural factor is often exacerbated by a national evaluation system that still focuses on traditional academic outcomes, rather than on the critical and collaborative thinking processes that are at the core of STEAM.

Research by Quigley et al. (2020) highlighting another conceptual challenge, namely the difficulty in designing an authentic and relevant STEAM curriculum. Teachers need time, collaboration, and resources to develop learning activities that connect science and the arts without losing focus on core learning outcomes. In many cases, the resulting integration is still superficial for example, simply adding elements of art as decoration without strengthening scientific understanding.

In addition, Voicu et al (2023) A cross-country study found that cultural challenges and public perceptions also play an essential role. In some contexts, art and creativity are still considered secondary aspects to science and mathematics. As a result, teachers and parents often view STEAM with skepticism, considering it less "academic" than conventional learning.

From a methodological perspective, these studies often use qualitative approaches, such as classroom observations and in-depth interviews, to explore teachers' perceptions and practical obstacles in the field. Although this method allows for a rich contextual understanding, its limitation lies in the generalization of results, since social and economic conditions between schools vary considerably. Experimental studies measuring the effectiveness of intervention strategies on improving teacher readiness are still relatively limited.

Critically, it can be concluded that the main obstacles to the implementation of STEAM include three dimensions: (1) the dimension of teacher competence, which is related to interdisciplinary literacy and creative pedagogy; (2) structural dimensions, including policies, facilities, and institutional support; and (3) the cultural dimension, which is related to values and perceptions of art and creativity in education. The implications of these findings show that the success of STEAM in elementary schools is not enough with curriculum innovation alone, but requires reform of the broader education ecosystem ranging from teacher training to paradigm changes in learning evaluation.

The results of a synthesis of various literature show that the application of the STEAM approach in primary schools has a positive impact on the improvement of students' 21st century skills, especially in the aspects of critical thinking, problem-solving, and creativity. These findings are in line with constructivist theories that emphasize that knowledge is built through direct experience and students' active involvement in the learning process (Jiang et al., 2023; Putri et al., 2024). In the context of STEAM, the integration of science, technology, engineering, art, and mathematics creates an authentic learning environment, where students can apply cross-disciplinary concepts to solve real problems. Research conducted by Afzal and Chusna reinforces these findings, showing that STEAM-based learning can improve the integration between students' conceptual understanding and practical skills (Afzal Vachhiyat & Tandel, 2025; Chusna et al., 2024).

Other findings suggest that project-based learning (project-based learning) is the most effective approach in the implementation of STEAM at the elementary school level (Laksmiwati et al., 2023; Laslo et al., 2024; Zakaria & Md Osman, 2024). This approach encourages students to design, create, and evaluate products or solutions, which demand collaboration as well as the integration of various disciplines. For example, a study conducted by Choirunnisa et al. (2023) shows that project-based STEAM models on alternative energy learning significantly improve students' science literacy compared to conventional learning. This reinforces the idea that the integration of the "Arts" element not only enriches creativity, but also helps students contextualize STEM knowledge in everyday life.

However, although the benefits of STEAM are widely recognized, the results of the study also show that several factors inhibit implementation in elementary schools. The most dominant factor is the limitation of teachers' competence in integrating the five disciplines in a balanced manner. Most teachers still view STEAM as a combination of science and technology activities, without harnessing the potential of art and design as an element of creative thinking (Ilma et al., 2023). In addition, the limitation of facilities and infrastructure such as technological devices, experimental materials, and pedagogical training is also a significant challenge in schools with limited resources (Susanta et al., 2025). In the Indonesian context, this challenge is exacerbated by the uneven STEAM curriculum in the national education system, so its implementation is still experimental and individual teacher initiatives.

These findings have important theoretical and practical implications. Theoretically, this study strengthens the relevance of interdisciplinary learning theory and experiential learning Kolb who places direct experience at the heart of knowledge construction (Ansari, 2025; Rahmi, 2024). STEAM became a concrete forum for this theory to be applied in elementary grades, by fostering active interaction between students and the learning environment. Practically, the results of this research can be the basis for the development of education policies that encourage systematic teacher training in the STEAM approach, as well as the preparation of learning modules that are in accordance with the characteristics of elementary school students. With adequate training support and resources, teachers can integrate technology and art more creatively into science and math learning.

However, there are some limitations in this study. First, because they are a literature study, the data analyzed depend on the completeness and quality of previous research reports, so the findings may not fully describe the empirical conditions in all primary school contexts. Second, most of the available literature comes from an international context, while research in Indonesia is still limited in number and scope. Therefore, generalization of results needs to be done carefully. For further research, it is recommended to conduct field studies that test the effectiveness of the STEAM model in a local context, for example through experimental design or classroom action research, so that more concrete and applicable empirical data can be obtained.

Overall, this study contributes by providing a comprehensive overview of the actual conditions of STEAM implementation in primary schools and offering a conceptual framework for its development. Through a synthesis of theories and empirical results, this research clarifies the position of STEAM not just as a pedagogical trend, but as an integral approach relevant to the demands of the 21st century. By strengthening teacher competencies, improving educational facilities, and instilling a collaborative culture in elementary schools, STEAM can be the foundation for educational transformation towards more creative, reflective, and future-oriented learning.

CONCLUSION

The STEAM approach in elementary schools has proven to be effective in fostering critical thinking, problem-solving, creativity, and student collaboration, in line with the demands of 21st century education. The integration between science, technology, engineering, art, and mathematics creates an authentic and meaningful learning experience, primarily through project-based learning. However, the implementation of STEAM still faces significant challenges, especially in terms of teacher readiness, limited facilities and infrastructure, and lack of systemic policy support. Efforts to develop teacher professionals, strengthen the cross-disciplinary curriculum, and provide contextual learning facilities are the keys to successful implementation. Conceptually, this study emphasizes that STEAM is not just a pedagogical innovation, but an integral educational strategy that is relevant to build the foundation of science literacy and creativity from the basic education level. For further research, it is

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recommended to conduct field empirical studies to test the effectiveness of the STEAM learning model in a more applicable and sustainable local context.

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