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THE IMPLEMENTATION OF THE STEAM APPROACH WITH INDONESIA'S LOCAL CULTURE IN MATHEMATICS LEARNING: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

The demands of 21st-century education require learning approaches that foster critical thinking, creativity, collaboration, and communication. Integrating Science, Technology, Engineering, Arts, and Mathematics (STEAM) is seen as a promising strategy to address these needs, yet its systematic implementation in mathematics learning in Indonesia, especially with local cultural contexts, remains underexplored. This study aimed to investigate how the STEAM approach has been applied in Indonesian mathematics education and how local culture is integrated. A systematic literature review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure transparency and rigor during the identification, screening, eligibility, and inclusion phases. The initial search yielded 259 articles from Scopus, ERIC, SINTA, Web of Science, and OpenAlex databases. After applying inclusion and exclusion criteria and removing duplicates, 20 articles published between 2014–2024 were analyzed in depth. To identify research trends, a bibliometric analysis using VOSviewer was performed to map keyword co-occurrences. The findings reveal that while the STEAM approach, combined with elements such as local art, traditional games, and architecture, successfully enhances student engagement and contextual learning, its application largely emphasizes procedural rather than conceptual understanding. Moreover, interdisciplinary collaboration and integration of local culture are not yet fully optimized to develop higher-order thinking. This review highlights the need for future studies to strengthen conceptual depth, promote authentic cross-disciplinary learning, and incorporate broader cultural perspectives in designing culturally responsive STEAM-based mathematics education.

Keywords: Local Culture, Mathematics Learning, STEAM.

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PRELIMINARY

The educational landscape of the 21st century demands critical thinking, creativity, collaboration, and communication skills (Zapata-Ros, 2019). The STEAM approach, integrating Science, Technology, Engineering, Arts, and Mathematics, is regarded as an effective means to address these needs by providing holistic and interdisciplinary learning experiences (Himmi et al., 2023; Rahmawati et al., 2022; Wannapiroon & Petsangsri, 2020). STEAM is a modification of the previously introduced integrated curriculum

concept STEM, with the addition of Art (Kwon et al., 2011). Previous research has shown that the STEAM approach helps reduce misconceptions, lowers cognitive load, and promotes student creativity (Chen & Huang, 2023; Ozkan & Topsakal, 2021). Consequently, incorporating STEAM into education can fulfill the objectives of 21st-century learning.

Although the STEAM approach has demonstrated benefits for students, there remains a lack of understanding regarding instructional design within this framework, despite its critical importance for classroom practice and research (Perignat & Katz-Buonincontro, 2019). The inconsistency in defining STEAM concepts and terminologies, including the elements of "Science", "Technology", "Engineering", "Art", and "Mathematics" has led to difficulties in articulating STEAM pedagogy and research (Aguilera & Ortiz-Revilla, 2021; Matsuura & Nakamura, 2021).

In Indonesia, the implementation of STEAM has garnered increasing attention, particularly through government initiatives such as the Ki Hajar STEM program (Naufal et al., 2024). The government has shown substantial interest in the broader implementation of STEAM-based learning (Leavy et al., 2023). However, despite these advancements, the STEAM approach is not formally embedded in Indonesia's educational curriculum. As a result, effective instructional designs for STEAM are poorly understood, leading to suboptimal implementation (Perignat & Katz-Buonincontro, 2019). Additionally, the elements of art and local cultural context are often overlooked (Aguilera & Ortiz-Revilla, 2021). On the other hand, research by Marufi et al. (2021) highlights the potential of local culture in enhancing students' relevance and understanding.

Mathematics, as one of the core elements of STEAM, plays a pivotal role as a foundational discipline for various other fields. However, integrating mathematics into STEAM projects often faces challenges, resulting in its role being reduced to a mere supporting tool for other disciplines rather than being explored as a central focus of learning (Tytler et al., 2023).

Despite the growing interest in the STEAM approach within education, there remains a significant gap in the literature regarding its systematic implementation in mathematics learning in Indonesia, particularly with respect to the integration of art and local cultural contexts. While previous studies have explored general perceptions of STEAM and its effects on student learning outcomes, few have examined how STEAM can be pedagogically designed and applied in mathematics education in a culturally responsive manner. Moreover, most existing research has overlooked the potential of local

culture and artistic elements to enrich STEAM-based learning experiences and improve students' conceptual understanding (Gunadi et al., 2023; Ilma et al., 2023; Naufal et al., 2024; Suparman et al., 2024). This study addresses these gaps by conducting a systematic literature review focused specifically on the implementation of STEAM and Indonesian local culture in mathematics learning. It offers a novel perspective by emphasizing the incorporation of STEAM and Indonesian local culture in mathematics learning.

The findings are expected to provide new insights into designing STEAM-based mathematics learning that aligns with both local and global needs while contributing to the global literature on STEAM education. The study addresses the following research questions:

1. How are the art components or other elements of STEAM integrated into mathematics learning?
2. How is the STEAM approach implemented in mathematics learning across different regions, educational levels, and subject topics in Indonesia?
3. What types of student projects are developed in mathematics learning using the STEAM approach?
4. How is local culture incorporated into mathematics learning through the STEAM approach in Indonesia?

METHODS

This study employed a systematic literature review using meta-analysis procedures guided by the PRISMA framework, which provides clear and comprehensive guidelines to ensure transparency and rigor in the identification, screening, eligibility assessment, and inclusion of relevant studies, thereby helping to minimize bias, improve replicability, and strengthen the overall validity of the review findings (Page et al., 2021). This systematic literature review aimed to explore and identify scholarly articles that discuss the implementation of the STEAM approach in mathematics education, with data sourced from various academic databases, as outlined in the identification section. The review followed several stages, including identification, screening, eligibility assessment, and exclusion, as outlined in the methodological procedure illustrated in Figure 1.

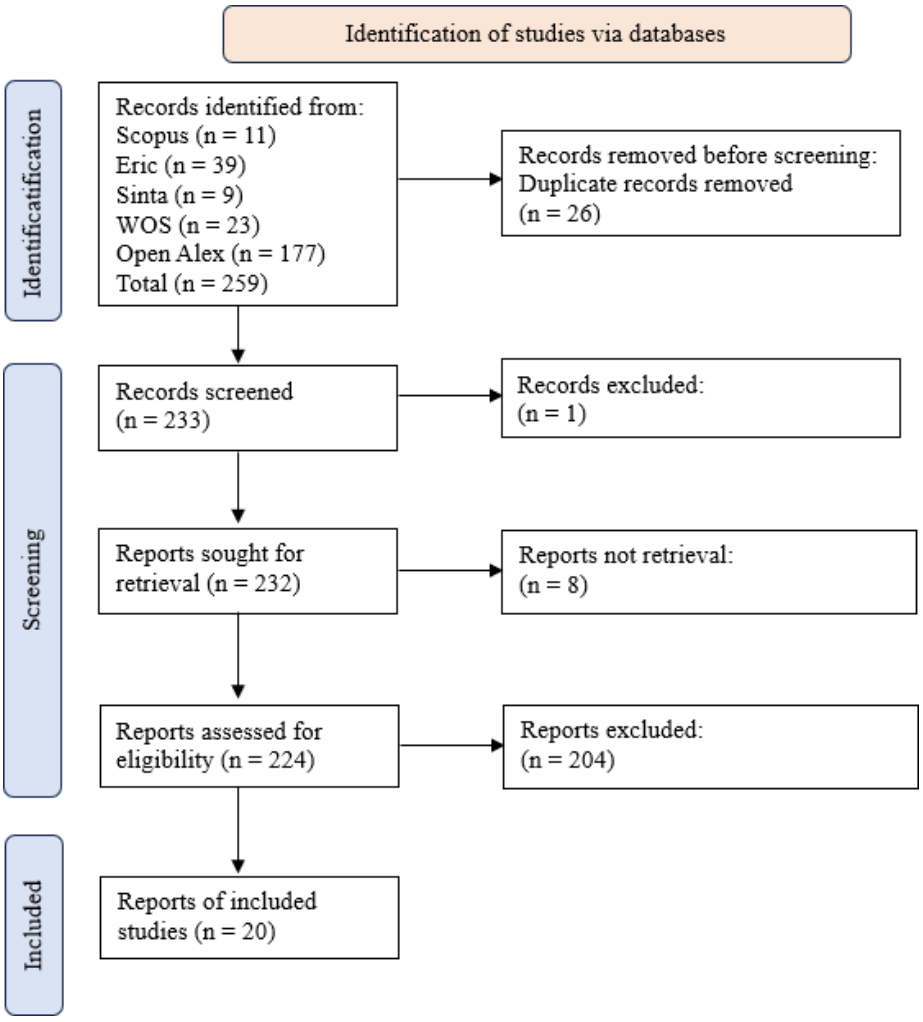

Figure 1. PRISMA Flow Chart

Phase 1: Identification

According to PRISMA standards, the identification phase is the initial step in conducting a systematic literature review. This phase involves searching for synonyms, related concepts, and variations of the main keywords. The keywords used in this study included "STEAM education or STEAM approach and Mathematics". Additionally, the researchers selected five primary databases: Scopus, ERIC, SINTA, Web of Science (WoS), and OpenAlex.

The objective of this phase was to provide additional options within the selected databases to identify more relevant articles for inclusion in the systematic review. Scopus and WoS offer advanced citation analysis and sophisticated search features, making them ideal for systematic reviews (Martín et al., 2018; Siswanto et al., 2024). Meanwhile, ERIC and SINTA focus specifically on education and local research (Paramitha & Agoestanto, 2023; Permatasari et al., 2022). OpenAlex provides open-access data, enabling researchers to access information more easily.

Phase 2: Screening

The researchers thoroughly identified and removed duplicate articles found across the Scopus, ERIC, SINTA, WoS, and OpenAlex databases. Subsequently, the publications were deeply evaluated to ensure they met the established criteria. A total of 259 articles were automatically retrieved using the sorting method within the databases. Following this, 26 duplicate articles were removed, and the remaining 233 articles were further screened using the inclusion and exclusion criteria. The inclusion and exclusion criteria in this systematic literature review were adapted from Ilma et al. (2023) because their clear and relevant guidelines, which consider publication type, journal quality, research location, authors' nationality, publication year, and research focus, align well with the purpose of this study and were further developed by the authors to suit the specific context and objectives.

To identify trends and research focuses related to the implementation of the STEAM approach and Indonesian local culture in mathematics education, a bibliometric analysis was conducted using VOSviewer software version 1.6.20. Bibliographic data were obtained from internationally indexed articles and processed in .ris format to identify relationships among keywords through co-occurrence analysis. The network mapping results revealed that the keyword "STEAM" occupies a central position, closely linked to several significant themes such as augmented reality, character education, design research, and creative commons attribution. These findings provide a solid foundation for this systematic study to map relevant literature and develop a conceptual framework for implementing a culturally contextualized STEAM approach in mathematics learning in the Indonesian context.

As part of the selection process, the researchers considered the publication time frame before conducting further analysis. Therefore, one of the inclusion criteria applied was selecting articles published between 2014-2024. A single article published after 2024 was excluded from the selection process before proceeding to the eligibility assessment stage. The inclusion and exclusion criteria is presented in Table 1.

Table 1. Inclusion and Exclusion Criteria

No	Category	Inclusion Criteria	Exclusion Criteria
1	Type of Publication	Articles published in journals	Articles published in conference proceedings, books, websites, blogs, etc.
2	Journal Specification	National journals published in Indonesia must have at least SINTA 2 accreditation, while international journals must be indexed in Scopus	National journals without accreditation or with SINTA 3 to 6 accreditation, and international journals not indexed in Scopus

3	Research Location	Indonesia	Abroad
4	Nationality of Authors	Indonesian authors, collaborations between Indonesian and foreign authors	Only foreign authors
5	Language	English and Indonesian	Other languages besides English and Indonesian
6	Publication Year	2014 – November 2024	Published before 2014
7	Focus	STEAM in mathematics education	STEAM in subjects other than mathematics

Phase 3: Eligibility

A total of 224 articles were prepared for the eligibility phase, which is the third step in the research process. Each title, abstract, and main content of the articles were carefully reviewed to ensure that they met the inclusion criteria outlined in Table 1 and were relevant to the research objectives. To maintain the quality of the review, only empirical studies published in journals were considered, and only articles written in English or Indonesian were included. Furthermore, only articles focused on the STEAM approach in mathematics education were selected. Using this strategy, 204 articles were eliminated, and 20 articles were deemed suitable for further review.

Phase 4: Inclusion

After three stages of selection, only those articles that fully met the criteria were included. As a result of the screening procedure, 20 articles were selected to be reviewed in this systematic literature review. All selected articles had objectives relevant to the implementation of the STEAM approach in mathematics education.

RESULT AND DISCUSSION

A total of 20 articles were selected and reviewed in this systematic literature review to examine the implementation of the STEAM approach in mathematics education. The distribution of the selected articles, published between 2014-2024, is presented in Figure 2.

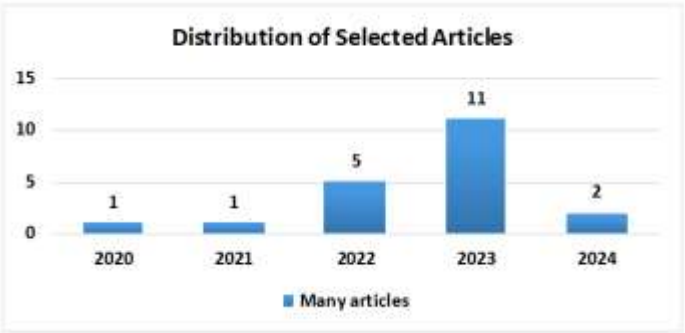

Figure 2. Distribution of Selected Articles Published Between 2014-2024

The aim of this systematic literature review is to explore the implementation of the STEAM approach in mathematics education. A total of 20 articles were reviewed and analyzed to comprehensively address the four research questions. The article is presented in Table 2.

Table 2. Relevant Research Findings

No	Authors	Years	Research Findings	Educational Level
1	Nindiasari et al	2024	The use of Augmented Reality for understanding three-dimensional geometry enhances students' problem-solving skills	Senior High School
2	Parhusip et al	2023	Batik motif design project using algebra concepts through Surfer software improves students' understanding of geometry	Senior High School
3	El Bedewy et al	2024	Traditional architecture modeling using GeoGebra, integrating art and mathematics in learning	-
4	Siregar et al	2023	Hydroponic project for elementary students to teach the concept of volume in solid geometry.	Elementary School
5	Apriandi et al	2023	Integration of local culture through the Taman Ancient Mosque in flat solid geometry projects increases student engagement.	Junior High School
6	Isamer et al	2023	Creation of traditional kite games teaching physics and mathematics concepts enhances students' numeracy.	Junior High School
7	Qomaria et al	2022	Application of ethno-STEAM in creating Madura game miniatures enhances students' collaboration skills.	Junior High School
8	Jayanti & Yunianta	2022	Measuring building height using trigonometric ratios connects mathematical concepts with real-life situations.	Vocational High School
9	Relmasira et al	2023	AI literacy in STEAM education using art and technology interactions in elementary school improves mathematical concept understanding.	Elementary School
10	Hapidin et al	2023	Using comic media to enhance maritime culture literacy in early childhood through STEAM.	Kindergarten
11	Sutama et al	2020	The flipped classroom model integrated with STEAM effectively improves students' problem-solving and analytical skills.	-
12	Akbar et al	2022	Problem-based learning with Android application in series and sequences improves students' problem-solving skills.	Senior High School

13	Ishartono et al	2023	The Flip Flop model integrated with STEAM enhances students' understanding of the composition of functions.	Senior High School
14	Mariana & Kristanto	2023	STEAM-CT integration with a focus on product design enhances students' critical thinking skills.	-
15	Suprapto et al	2023	Development of student worksheets integrated with local culture, such as Benteng Pendem, enhances creativity and mathematical skills.	Junior High School
16	Ma'rufi et al	2021	Integration of Ethno-STEM in mathematics learning with traditional tools improves students' understanding of geometry concepts.	-
17	Adnan et al	2023	Development of STEAM textbooks integrating educational character and local culture enhances student engagement in elementary school	Elementary School
18	Kamila et al	2023	Batik motif design project using Rainbow Vertex Antimagic Coloring (RVAC) effectively combines art and mathematics.	-
19	Pratiwi & Khotimah	2022	Application of STEAM approach using Microsoft Teams media in creating hydraulic lifts.	-
20	Suhardi & Utama	2022	Use of 4Dframe in creating miniatures of water towers and straw bridges teaches interdisciplinary concepts of engineering and geometry.	-

How are the art components or other STEAM components integrated into mathematics learning?

Through the systematic literature review exploration, a total of five articles focused on findings regarding the integration of STEAM components in mathematics education. The studies by Isamer et al. (2023) and Kamila et al. (2023) both highlight how STEAM integration can facilitate contextual, project-based learning, but with different focuses on local cultural contexts. Kamila et al. (2023) emphasize batik as a cultural representation by combining the mathematical concept of Rainbow Vertex Antimagic Coloring (RVAC), while Isamer et al. (2023) utilize a traditional kite-making project. Both studies demonstrate that Art is not merely decorative but serves as a bridge to strengthen connections among science, technology, engineering, and mathematics concepts. A comparative analysis shows that although the cultural contexts differ, both successfully

leverage local cultural potential to connect conceptual knowledge with practical application. This supports the idea that contextualized STEAM approaches can enhance the relevance of mathematics learning.

Relmasira et al. (2023) expand the dimension of technology integration by implementing AI literacy within STEAM education at the elementary level. Unlike the previous two studies, which emphasize cultural context, this research adds a contemporary digital literacy component through the use of Google Auto Draw to merge art and technology. Synthesizing these three studies reveals a trend that technology is not merely a supporting tool but also a medium for developing students' visual creativity while introducing them to modern technologies relevant to the digital era. This confirms the importance of integrating up-to-date technology to enrich STEAM approaches without neglecting the local context that grounds the learning experience.

The studies by Mariana & Kristanto (2023) and Sutama et al. (2020) both apply problem-solving-based approaches but through different learning models. Sutama et al. (2020) utilize the flipped classroom model to encourage students to independently explore solutions while combining STEAM elements, whereas Mariana & Kristanto (2023) focus on the STEAM-CT (Computational Thinking) approach to teach simple machine concepts. A comparative analysis shows that both studies emphasize the critical role of technology and engineering in designing practical solutions, complemented by the inclusion of artistic elements to make learning products more aesthetically engaging. This synthesis reinforces the view that combining STEAM with innovative learning models such as flipped classrooms or computational thinking can broaden creative opportunities while sharpening higher-order thinking skills.

A key finding across all five articles is the integration of local culture effectively enhances student engagement in mathematics learning. This synthesis of findings confirms that STEAM learning connected to cultural and project-based contexts can facilitate constructivist learning, where students build knowledge through authentic, real-world experiences. This aligns with Perignat & Katz-buonincontro (2019), who emphasize the importance of authentic contexts in STEAM education. Therefore, future STEAM learning development should prioritize a balance between mastering cutting-edge technology and empowering local culture to foster holistic 21st-century skills.

How is the implementation of the STEAM approach in mathematics learning across Indonesia, based on educational levels and topics?

The findings from the systematic literature review covering research from 2014 to 2024 identified nine studies focusing on the implementation of the STEAM approach in mathematics education in Indonesia, categorized by educational level and topic. The distribution based on topics is presented in Figure 3.

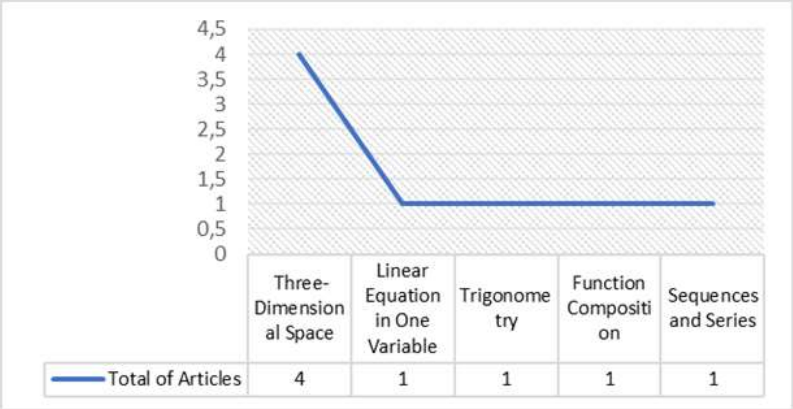

Figure 3. Distribution of STEAM Approach by Mathematics Educational Topics in Indonesia

The distribution topic of STEAM approach in mathematics education in Indonesia, included: three-dimensional space, linier equation in one variable, trigonometry, function composition, and sequences and series. While the distribution of selected articles based on educational levels is shown in Figure 4.

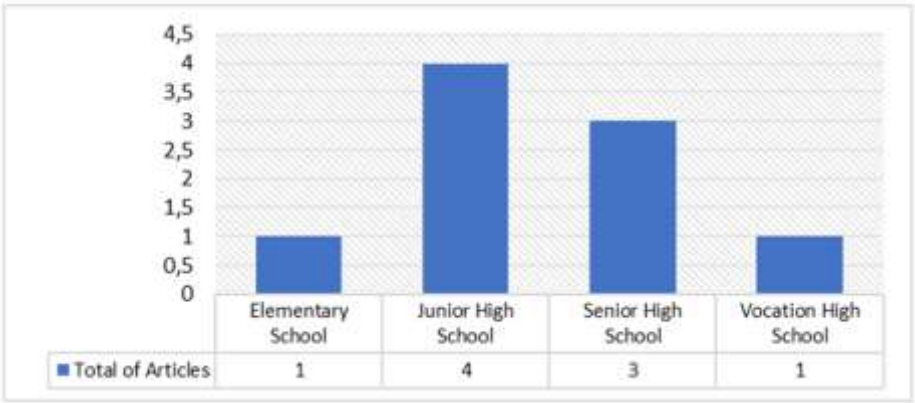

Figure 4. Distribution of the STEAM Approach Across Educational Levels in Indonesia

The topics discussed in Figure 4 encompass various aspects, the pattern showed that the depth of mathematics content taught through the STEAM approach in Indonesia still tends to stay at the procedural level. At the elementary level, projects like hydroponics mainly help students calculate volume but do not guide them to understand deeper relationships in spatial geometry (Siregar, et al., 2023). In junior high schools, activities

such as developing student worksheets about local historical sites focus on calculating surface area, volume, or solving simple equations, but do not encourage students to generalize or create proofs (Apriandi et al., 2023; Suprapto et al., 2023). Similarly, in traditional game projects (Isamer et al., 2023; Qomaria et al., 2022), the topic of linear equations in one variable (SPLSV) is only directed toward calculating the value of the variable without exploring the algebraic relationships more conceptually. At the senior high school level, topics like function composition, sequences and series, and three-dimensional geometry are more advanced, but the learning mostly remains on routine problem-solving instead of helping students reason formally or prove theorem (Akbar et al., 2022; Ishartono et al., 2022; Nindiasari et al., 2024). Similarly, in vocational schools, measuring building heights with trigonometry trains students to use formulas but does not lead them to explore trigonometric identities in depth (Jayanti et al., 2022).

In general, the studies show that STEAM activities do make mathematics more interesting and relevant by using culture and technology, but they do not yet fully develop students' higher-order thinking skills such as abstraction, generalization, and proof. Therefore, future implementations should pay more attention to strengthening conceptual understanding in each topic, not just procedural skills.

What types of student projects are developed in mathematics learning using the STEAM approach?

This study identifies various STEAM projects undertaken by students in mathematics education, based on an article review through systematic literature review. From the total of eight articles reviewed, the following findings describe the types of projects implemented:

1. Architectural Miniatures: This includes projects such as the creation of miniatures of the Warka Water Tower, Batam-Bintan Straw Bridge, and planting machines, aimed at understanding the technical and geometric aspects within the context of local culture (Suhardi & Utama, 2022).
2. Hydraulic Technology: This includes the creation of a hydraulic lift, which introduces physics and mathematics concepts through practical application (Pratiwi & Khotimah, 2022).
3. Batik Pattern Design: Projects on designing batik patterns using the Rainbow Vertex Antimagic Coloring (RVAC) concept emphasize the integration of art and mathematics (Kamila et al., 2023). Additionally, there are batik pattern creations

inspired by algebraic surfaces using Surfer software, combining technology with artistic creativity (Parhusip et al., 2023).

4. Hydroponic Projects: These projects aim to teach the concept of volume in spatial geometry through hands-on experiences (Siregar et al., 2023).
5. Traditional Games Projects: For example, the kite project, which not only teaches physics concepts but also incorporates cultural values (Isamer et al., 2023). Additionally, there is the creation of a traditional Madura game, Pesapean, which serves as a medium for understanding geometric concepts and social interaction (Qomaria et al., 2022).
6. Building Height Measurement Using Trigonometric Ratios: This project teaches students the application of mathematics in real-world contexts (Jayanti et al., 2022).

STEAM projects in mathematics education reflect effective multidisciplinary integration that enhances students' understanding of mathematical concepts while enriching their learning experiences. The identified projects encompass aspects of engineering (architecture, hydraulics), art (batik design), technology, and local culture (traditional games, local building miniatures). All of these projects do not focus solely on a single discipline but combine various STEAM components to create a holistic learning experience.

How is local culture incorporated into mathematics learning through the STEAM approach in Indonesia?

Through an exploration of articles using systematic literature review, 10 research articles were identified that focus on the incorporation of local culture in STEAM-based mathematics education in Indonesia. The findings highlight that the culture integrated into the learning process involves traditional tools or methods, local art or architecture, and culturally relevant practices. This is in line with the view of Marufi et al. (2021), who state that the integration of culture in STEM can be achieved in three ways: by using traditional tools or methods to teach mathematical concepts, studying geometric forms in local art or architecture, and applying real-life examples to construct mathematical problems.

Traditional tools or methods, such as the Madura traditional game Pesapean (Qomaria et al., 2022) and the traditional kite game (Isamer et al., 2023), serve as means to teach mathematical concepts through hands-on experiences. Additionally, various forms of architecture, such as the Warka Water Tower, the Batam-Bintan Straw Bridge (Suhardi & Utama, 2022), and the Old Mosque Taman and Benteng Pendem in Madiun (Apriandi et

al., 2023; Suprapto et al., 2023), provide insights into geometry. The Kutai house in Pasir Salak is also associated with geometric principles taught in STEAM textbooks (Adnan et al., 2023). On the other hand, traditional buildings such as the Uma Mbatangu house in Sumba, Pura Induk Besakih in Bali, the Mbaru Niang house in East Nusa Tenggara, as well as the Rumah Gadang and the Great Mosque of Nurussalam in Batulicin, all represent geometric values in a cultural context (El Bedewy et al., 2024). Equally important, batik pattern creation serves as a concrete example of the application of geometry in local art (Parhusip et al., 2023). In the context of relevant cultural practices, maritime cultural literacy in early childhood represents an example of the application of mathematics that is closely tied to everyday life.

In short, these findings show that incorporating local culture through traditional tools, architecture, art, and everyday practices makes mathematics learning in Indonesia more meaningful, contextual, and engaging. However, future research should continue to explore how this cultural integration can also support deeper mathematical understanding and higher-order thinking skills.

CONCLUSION

Based on this systematic literature review, it can be concluded that the STEAM approach in mathematics education in Indonesia has been creatively implemented through the integration of science, technology, engineering, art, mathematics, and local cultural contexts such as batik, traditional games, and local architecture. This approach has proven effective in increasing student engagement and making mathematics learning more relevant to real-life contexts. However, its implementation still tends to emphasize procedural fluency rather than deeper conceptual understanding, generalization, or formal reasoning. Interdisciplinary collaboration, which is central to STEAM, is often implied but not yet fully realized in practice, and most studies are limited to small-scale, short-term interventions with minimal evidence of long-term impact. In addition, a key limitation of the current research is that it mainly focuses on exploring cultural elements within Indonesia, which means that insights into how local culture interacts with global or cross-cultural contexts are still lacking. Therefore, future research should focus on strengthening conceptual depth, fostering authentic cross-disciplinary collaboration, exploring non-cognitive outcomes, expanding cultural perspectives beyond local contexts, and conducting longitudinal studies to ensure the sustainability and transformative potential of STEAM in developing students' mathematical thinking and cultural awareness.

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