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Integrating Arts into STEM: A Systematic Review of STEAM Education Practices in Southeast Asia

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ABSTRACT

STEAM (Science, Technology, Engineering, Arts, and Mathematics) education has gained increasing attention as an interdisciplinary approach for developing creativity, critical thinking, collaboration, and problem-solving skills essential for the 21st century. Despite its growing adoption across Southeast Asia, evidence regarding implementation practices, challenges, and future directions remains fragmented. This study aims to systematically review STEAM education practices in five Southeast Asian countries, namely Malaysia, Indonesia, Thailand, Vietnam, and the Philippines. Guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, 49 studies published between 2016 and 2025 were retrieved from Scopus and Web of Science databases and analyzed using thematic synthesis. The findings indicate that project-based learning, technology integration, culturally responsive pedagogy, and sustainability-oriented approaches are the predominant practices implemented across the region. However, several barriers continue to hinder effective implementation, including inadequate teacher readiness, limited infrastructure and resources, policy inconsistencies, and challenges in assessing higher-order skills. The review further identifies opportunities to strengthen STEAM education through sustained professional development, pedagogically driven technology adoption, localized curriculum design, improved assessment frameworks, and stronger policy and leadership support. This study contributes to a comprehensive understanding of the current landscape of STEAM education in Southeast Asia and provides evidence-based recommendations to support future educational practices, policymaking, and research in the region.

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1. Introduction

STEAM education, which integrates Arts into Science, Technology, Engineering, and Mathematics (STEM), has emerged as a transformative approach to foster creativity, critical thinking, and interdisciplinary learning

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(Kummanee et al., 2020; Siregar et al., 2023; Ekayana et al., 2025). Globally, STEAM is recognized for its potential to equip learners with 21st-century skills, preparing them for innovation-driven economies and complex problem-solving (How & Yung, 2019; Arpaci et al., 2023). By combining analytical and creative domains, STEAM aims to develop holistic competencies that traditional STEM approaches often overlook.

In Southeast Asia, STEAM education is gaining momentum through various initiatives in formal education settings, from early childhood to higher education (Awang et al., 2020; Bureekhampun & Mungmee 2020; Oanh & Dang, 2025). Countries such as Malaysia, Indonesia, Philippines, Thailand, and Vietnam have introduced STEAM-based projects, technology enhanced learning, and curriculum reforms (Naufal et al., 2024; Laksmiwati et al., 2023). However, implementation remains inconsistent due to challenges such as limited resources, insufficient teacher training, and lack of empirical evidence on effectiveness (Suharni et al., 2025; Nguyen et al., 2024; Laksmiwati et al., 2023). These gaps highlight the need for a systematic synthesis of existing research to inform policy and practice.

This review addresses the following research questions:

1. What are the prevailing practices and approaches to STEAM education in Southeast Asia?
2. What challenges and barriers are reported in implementing STEAM education across different educational levels?
3. What opportunities and recommendations emerge from the reviewed studies to strengthen STEAM education in the region?

Previous studies have documented a wide range of approaches for implementing STEAM education in Southeast Asia. Project-based learning, design thinking, gamification, digital learning ecosystems, and inquiry-based learning are among the most frequently adopted pedagogical strategies (Kummanee et al., 2020; Suryanti et al., 2023; Rahmawati et al., 2025). Furthermore, technology-enhanced approaches incorporating augmented reality, virtual reality, mobile learning, and artificial intelligence have been increasingly integrated into STEAM learning environments to promote student engagement and problem-solving skills (Siregar et al., 2023; Nindiasari et al., 2024; Hakim et al., 2025). These studies suggest that STEAM education is increasingly viewed as a mechanism for fostering interdisciplinary learning and 21st-century competencies.

Despite these developments, several studies have highlighted persistent challenges in implementing STEAM education. Teacher readiness, limited professional development opportunities, inadequate technological infrastructure, and insufficient instructional resources continue to hinder effective implementation across educational levels (Suharni et al., 2025; Laksmiwati et al., 2023; Naufal et al., 2024). Additionally, inconsistencies in curriculum frameworks and limited assessment mechanisms have created difficulties in evaluating the effectiveness of STEAM initiatives (Ramli et al., 2025; Manh-Tuan et al., 2025). Such challenges suggest a need for more coordinated efforts at institutional and policy levels.

At the same time, the literature points to numerous opportunities for strengthening STEAM education in the region. Studies have emphasized the importance of sustained teacher professional development, culturally responsive curriculum design, technology integration, and sustainability-oriented learning experiences (Muzakkir et al., 2024; Sumarni et al., 2025; Rahmawati et al., 2022). However, existing studies often focus on individual countries, educational levels, or specific interventions, resulting in fragmented evidence regarding STEAM practices across Southeast Asia. Consequently, a comprehensive synthesis of the literature is needed to identify prevailing practices, implementation challenges, and future directions for STEAM education in the region.

This study adopts a Systematic Literature Review (SLR) guided by the PRISMA framework, ensuring a rigorous and transparent process for identifying, screening, and analyzing relevant studies published between 2016 and 2025. The review synthesizes findings from peer-reviewed journal articles in the fields of social sciences and education indexed in the Scopus and Web of Science (WoS) databases to provide clear guidance on the current state of STEAM education in Southeast Asia. The aim is to identify trends, challenges, and opportunities, offering evidence-based recommendations for educators, policymakers, and researchers to enhance interdisciplinary learning and innovation across the region.

2. Methodology

The systematic review was conducted in three main stages to identify and select relevant studies for this research. The first stage involved determining appropriate keywords and their synonyms using resources such as thesauruses, encyclopedias, dictionaries, and prior studies. Once all relevant terms were finalized and presented in Table 1, search strings were constructed for the Scopus and Web of Science (WoS) databases. Using these search strings, the initial retrieval process yielded 151 articles from Scopus and 46 articles from WoS, forming the preliminary dataset for this review.

Table 1: The search strings

Database	Search equation
Scopus	ALL = ('STEAM EDUCATION') AND (LIMIT TO ('COUNTRY/TERRITORY')) AND (LIMIT TO ('OPEN ACCESS'))
Web of Science	ALL = ('STEAM EDUCATION') AND (LIMIT TO ('COUNTRY/ REGION')) AND (LIMIT TO ('OPEN ACCESS'))

2.1 Screening

In the screening phase, duplicate records were checked and none were found. Several inclusion and exclusion criteria were then applied to refine the dataset. For inclusion, only studies written in English, published as journal articles, and categorized under the subject areas of social sciences and education were considered. The timeline was restricted to publications from 2016 to 2025. For exclusion, papers from different countries, non-open-access articles, books, book chapters, book series, review papers, and conference proceedings were removed. Based on the established inclusion and exclusion criteria, a total of 74 publications from Scopus and 28 publications from Web of Science (WoS) were excluded during the screening process. Consequently, 77 publications from Scopus and 18 publications from WoS were retained for further assessment.

2.2 Eligibility

At the eligibility stage, a total of 77 publications from Scopus and 18 publications from Web of Science (WoS) were subjected to full-text assessment. Each article's title, abstract, and content were carefully examined to ensure compliance with the inclusion criteria and alignment with the objectives of this study. During this process, 35 publications from Scopus and 11 publications from WoS were excluded because they did not fall within the scope of STEAM education. Consequently, as shown in Table 2, 42 publications from Scopus and 7 publications from WoS were retained for the final review, resulting in a total of 49 studies included in the qualitative analysis.

Table 2: The selection criterion is searching

Criterion	Inclusion	Exclusion
Country/ Region	Malaysia, Indonesia, Philippines, Vietnam, Thailand	Other than Southeast countries
Language	English	Non-English
Timeline	2016-2025	>2016
Literature type	Journal (Article)	Conference proceedings, Book, Review, Chapters
Subject Area	Social sciences and Education	Other than Social sciences and Education

2.3 Data abstraction and analysis

Following the identification, screening, and eligibility stages of the PRISMA framework, the final set of selected articles was subjected to a detailed review and thematic analysis. Data were systematically extracted from each study, including publication information, country of study, educational level, research objectives, research design, sample characteristics, and key findings related to STEAM education practices. The extracted information was subsequently organized into a data extraction matrix to facilitate comparison across studies and ensure consistency throughout the review process.

The thematic analysis was guided by the research questions of this study. During the coding process, the findings of each article were carefully reviewed to identify recurring concepts, issues, and practices related to STEAM education. Similar codes were grouped into broader categories, which were then synthesized into overarching themes. This process enabled the identification of common patterns and relationships across the selected studies while maintaining alignment with the objectives of the review.

An integrative synthesis approach was employed to combine findings from studies adopting qualitative, quantitative, and mixed-method research designs. Rather than analyzing studies based on methodological differences, the findings were synthesized collectively to provide a comprehensive understanding of STEAM education practices in Southeast Asia. The analysis generated three main themes corresponding to the research questions: (i) prevailing practices and approaches to STEAM education, (ii) challenges and barriers in implementing STEAM education across different educational levels, and (iii) opportunities and recommendations for strengthening STEAM education in the region. This systematic and transparent process ensured that the review captured comprehensive insights into the trends, challenges, and future directions of STEAM education in Southeast Asia.

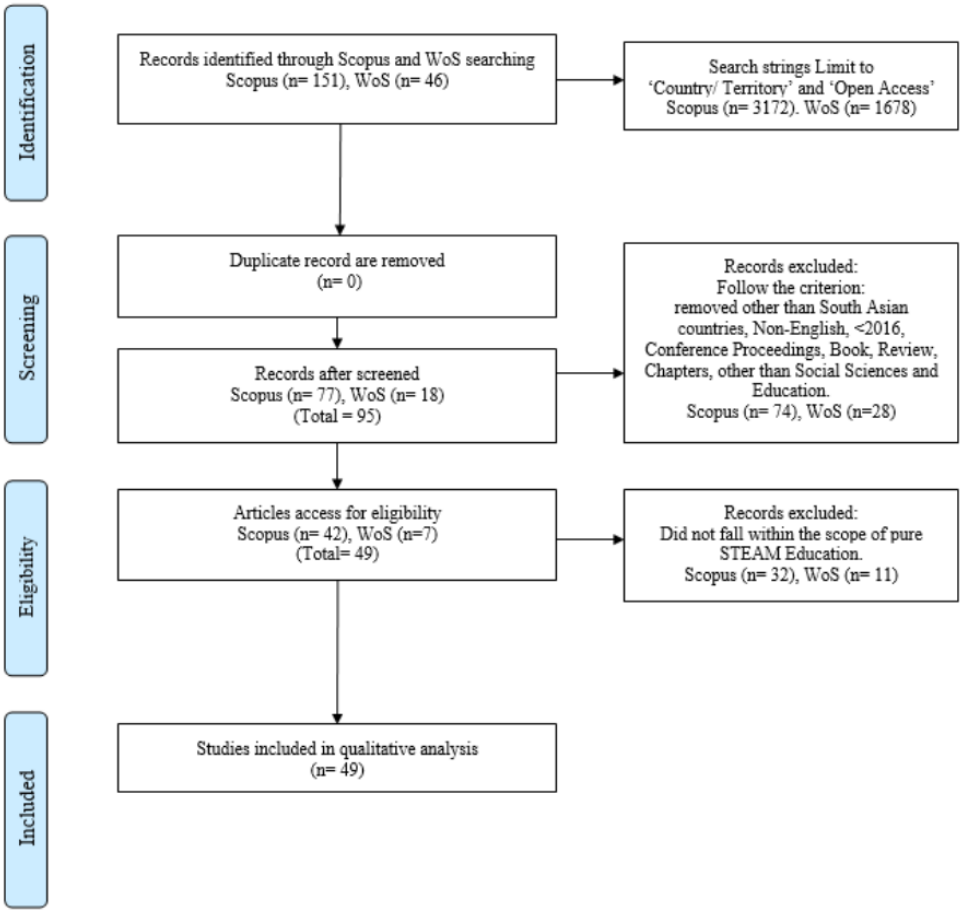

Figure 1. Flow diagram of the proposed searching study

3. Results and Discussion

Findings from the study conducted between 2016 and 2025 using the systematic literature review (SLR) method have been summarized in Table 3. The analysis provides insights into the current state of STEAM education practices in Southeast Asia, highlighting key trends, challenges, and opportunities identified across the reviewed studies. The synthesis reveals variations in implementation strategies, teacher readiness, curriculum integration, and technological adoption, alongside persistent barriers such as resource limitations and policy inconsistencies. These findings serve as a foundation for understanding how STEAM education is evolving in the region and inform recommendations for future research and practice.

Table 3: Thematic synthesis of STEAM education studies in Southeast Asia (2016–2025)

Theme	Reference	Country	Main Contribution
Pedagogical Approaches	Ekayana et al. (2025)	Indonesia	STEAM-PjBL framework improved creative thinking skills and learning achievement.
	Suryanti et al. (2023)	Indonesia	STEAM-PjBL enhanced elementary students' scientific literacy.
	Oanh & Dang (2025)	Vietnam	STEAM-PjBL strengthened engineering students' 21st-century skills.
	Rahmawati et al. (2025)	Indonesia	Design Thinking integrated with STEAM improved environmental literacy and student engagement.
	Rahmawati et al. (2022)	Indonesia	Ethical Dilemma-STEAM model supported sustainability-based learning.
	Zaqiah et al. (2024)	Indonesia	STEAM promoted collaboration and creativity among students.
	Ahmad et al. (2021)	Indonesia	STEAM-based learning organization increased students' creative thinking.
	Chansaengsee (2023)	Thailand	STEAM enhanced 21st-century skills in multicultural classrooms.
	Taibo & Liang (2022)	Thailand	STEAM facilitated the development of children's engineering thinking.
	Anito & Morales (2019)	Philippines	Proposed the Philippine STEAM pedagogical model and learning ecosystem.
	Arpaci et al. (2023)	Malaysia	STEAM learning modules positively influenced science learning outcomes.
Technology Integration	Kummanee et al. (2020)	Thailand	STEAM gamification supported vocational innovation and digital learning ecosystems.
	Siregar et al. (2023)	Indonesia	Mobile-based STEAM projects improved reasoning skills among elementary students.
	Hakim et al. (2025)	Indonesia	VR-integrated STEAM enhanced engagement in engineering education.
	Nindiasari et al. (2024)	Indonesia	AR-supported STEAM improved geometry problem-solving skills.
	How & Hung (2019)	Malaysia	Introduced AI-thinking within STEAM education.
	Relmasira et al. (2023)	Indonesia	Promoted AI literacy in elementary STEAM education.

	Yunianto et al. (2024)	Indonesia	Computational Thinking (CT) integration enhanced creativity through Batik-based STEAM learning.
	Wannapiroon & Petsangsri (2020)	Thailand	STEAMification improved creative thinking and innovation in flipped classrooms.
	Wannapiroon & Pimdee (2022)	Thailand	Virtual classrooms supported creativity and innovation skill development.
	Nguyen H. et al. (2024)	Vietnam	Design Thinking-based STEAM lessons enhanced technology competence.
	Prahani et al. (2024)	Indonesia	Evaluated the role of ChatGPT research in STEAM education.
Teacher Readiness & Professional Development	Manh-Tuan et al. (2025)	Vietnam	Investigated factors influencing preschool teachers' persistence in STEM implementation.
	Nguyen M. et al. (2024)	Vietnam	Examined factors affecting preschool teachers' implementation of STEAM activities.
	Lam et al. (2023)	Vietnam	Assessed competencies of future early childhood educators in implementing STEAM.
	Pransiska et al. (2025)	Indonesia	Explored teachers' readiness and acceptance of STEAM-oriented e-books.
	Perez et al. (2024)	Philippines	Developed inquiry-based STEAM teaching materials for pre-service teachers.
	Laksmiwati et al. (2023)	Indonesia	Identified implementation perspectives from experts and policymakers.
	Laksmiwati et al. (2024)	Indonesia	Highlighted teacher innovation through design heuristics in STEAM environments.
	Awang et al. (2020)	Malaysia	Examined STEAM teaching practices in preschool education.
	Bureekhampun & Mungmee (2020)	Thailand	Developed effective STEAM activity designs for preschool students.
Cultural & Sustainability Integration	Ha (2023)	Vietnam	Connected STEAM learning with Vietnamese cultural heritage through Moon-Shaped Lute production.
	Sumarni et al. (2025)	Indonesia	Ethno-STEAM enhanced collaboration and creative thinking among prospective teachers.
	Adnan et al. (2023)	Malaysia	Integrated local wisdom and character education into STEAM textbooks.
	Muzakkir et al. (2024)	Malaysia	Developed and validated the Q-STEAM module integrating Islamic values.
	Ellianawati et al. (2024)	Indonesia	Renewable energy projects improved creativity and critical thinking.
	Djam'an (2025)	Indonesia	Integrated environmental education into STEAM for sustainability.
	Khoiri et al. (2023)	Indonesia	Combined STEAM and ESD to improve concept understanding and creativity.

	Rahim et al. (2024)	Indonesia	Applied STEAM-PjBL in vocational welding education.
Challenges & Barriers	Suharni et al. (2025)	Indonesia	Reported challenges in integrating literacy and STEAM in early childhood classrooms.
	Naufal et al. (2024)	Indonesia	SWOT analysis revealed implementation weaknesses and limitations.
	Nguyen M. et al. (2024)	Vietnam	Identified barriers affecting preschool teachers' STEAM implementation.
	Manh-Tuan et al. (2025)	Vietnam	Highlighted institutional influences affecting implementation persistence.
	Laksmiwati et al. (2023)	Indonesia	Reported policy and implementation constraints from expert perspectives.
Opportunities & Recommendations	Ramli et al. (2025)	Malaysia	Proposed STEAM-ing Criteria for integrating science modules with visual arts.
	Worapun & Nuangchalerm (2024)	Thailand	Developed an instructional model to foster creative thinking.
	Belbase et al. (2021)	Thailand	Discussed future priorities, prospects, and challenges in STEAM education.
	Imamyartha et al. (2024)	Indonesia	Expanded STEAM pedagogy into foreign language education through the 6E framework.
	Tan et al. (2020)	Malaysia	Demonstrated positive outcomes of STEAM integration in electricity learning.
	Sutama et al. (2020)	Indonesia	Recommended flipped classroom integration with STEAM learning.

4. Discussion

4.1 What are the prevailing practices and approaches to STEAM education in Southeast Asia?

The findings indicate that Project-Based Learning (PjBL) has become the dominant pedagogical approach for STEAM implementation across Southeast Asia. The widespread adoption of PjBL may be attributed to its alignment with the interdisciplinary nature of STEAM, as it allows learners to integrate scientific knowledge, technological skills, engineering design, artistic creativity, and mathematical reasoning within authentic problem-solving contexts (Ekayana et al., 2025; Sumarni et al., 2025; Suryanti et al., 2023; Rahmawati et al., 2022). Unlike traditional teacher-centred approaches, PjBL encourages active learner participation and knowledge construction, which may explain its consistent association with improvements in creativity, collaboration, and critical thinking. However, while many studies reported positive outcomes, relatively few examined the long-term sustainability of these gains, suggesting the need for further investigation into whether the benefits of STEAM-based projects extend beyond short-term interventions.

The findings also suggest that STEAM implementation in Southeast Asia is increasingly contextualized through place-based and culturally relevant learning experiences. Studies integrating local traditions and cultural heritage, such as the Moon-Shaped Lute project in Vietnam, demonstrate how STEAM education can move beyond technical skill development to strengthen students' cultural awareness and identity (Ha, 2023). This reflects an important shift from adopting generic STEAM models toward developing locally relevant pedagogical approaches. Such contextualization is particularly important in Southeast Asia, where diverse cultural traditions and local knowledge systems can serve as meaningful entry points for interdisciplinary learning. Nevertheless, the effectiveness of these localized

approaches remains underexplored, as most studies focused on immediate learning outcomes rather than broader cultural or societal impacts.

Technology integration emerged as another prominent characteristic of STEAM education practices in the region. The increasing use of mobile applications, virtual reality (VR), augmented reality (AR), gamification, and digital learning ecosystems reflects growing recognition of technology as a medium for enhancing engagement and facilitating experiential learning (Kummanee et al., 2020; Siregar et al., 2023; Hakim et al., 2025; Nindiasari et al., 2024). While these technologies offer opportunities to create immersive learning experiences, their success appears to depend largely on pedagogical integration rather than technological novelty alone. Several studies emphasized improvements in engagement and problem-solving, yet there remains limited evidence regarding how technology-enhanced STEAM learning affects deeper conceptual understanding across different educational contexts. This suggests that educators should be cautious about viewing technology as a standalone solution and instead focus on how technological tools support meaningful learning processes.

Furthermore, the inclusion of Education for Sustainable Development (ESD), environmental literacy, and local wisdom themes indicates a growing effort to align STEAM education with broader societal and environmental priorities (Adnan et al., 2023; Khoiri et al., 2023; Djam'an, 2025). This trend reflects the recognition that contemporary educational challenges require interdisciplinary solutions that extend beyond academic achievement. By connecting STEAM learning to sustainability and community issues, educators can encourage students to apply knowledge in ways that are socially relevant and locally meaningful. However, the concentration of such studies within a limited number of countries, particularly Indonesia, suggests an imbalance in regional research representation and highlights opportunities for further exploration in other Southeast Asian contexts.

Another notable finding is the emphasis on teacher capacity building through professional development programmes and readiness assessments (Manh-Tuan et al., 2025; Pransiska et al., 2025; Suharni et al., 2025; Laksmiwati et al., 2023). The prominence of teacher-focused initiatives suggests that successful STEAM implementation is increasingly recognized as dependent on educator competence and confidence. This finding is consistent with the interdisciplinary demands of STEAM, which require teachers to move beyond traditional subject boundaries. However, the strong focus on teacher readiness across multiple studies may also indicate persistent concerns regarding educators' preparedness to implement STEAM effectively. Therefore, while professional development initiatives are becoming more common, further attention should be given to evaluating their long-term effectiveness and their impact on classroom practice.

Overall, the prevailing practices identified in this review demonstrate that STEAM education in Southeast Asia is evolving beyond simple STEM integration toward more holistic, learner-centred, and contextually responsive approaches. The growing emphasis on project-based learning, technology integration, cultural relevance, sustainability, and teacher professional development reflects an effort to equip learners with competencies needed for an increasingly complex and interconnected world. Nevertheless, the uneven distribution of studies across countries and the predominance of short-term intervention research indicate that the field remains in a developmental stage, requiring more longitudinal and cross-country investigations to establish stronger evidence for sustainable STEAM implementation across the region.

4.2 What challenges and barriers are reported in implementing STEAM education across different educational levels?

The findings reveal that challenges associated with STEAM implementation in Southeast Asia extend beyond individual classroom practices and reflect broader systemic issues within educational institutions. Although teacher readiness is frequently identified as a key barrier, the issue appears to be more complex than simply a lack of pedagogical knowledge. The interdisciplinary nature of STEAM requires educators to move beyond traditional subject-specific teaching approaches and adopt new instructional roles that integrate multiple domains of knowledge. Consequently, many teachers may experience uncertainty when implementing STEAM because they are expected to facilitate learning experiences that require expertise across science, technology, engineering, arts, and mathematics simultaneously (Manh-Tuan et al., 2025; Pransiska et al., 2025; Suharni et al., 2025; Laksmiwati et al.,

2023). This challenge is particularly evident in early childhood education, where teachers must balance developmental appropriateness with interdisciplinary learning expectations (Awang et al., 2020; Manh-Tuan et al., 2025).

The persistence of teacher-related barriers also suggests that professional development initiatives may not yet be sufficiently aligned with the practical demands of STEAM implementation. While training programmes are increasingly available, the findings indicate that many educators continue to struggle with translating theoretical knowledge into classroom practice (Oanh & Dang, 2025; Rahim et al., 2024). This may indicate that existing professional development programmes tend to focus on introducing STEAM concepts rather than providing sustained coaching, collaborative planning opportunities, and long-term implementation support. Consequently, improving teacher competence alone may not be sufficient unless accompanied by organizational support structures that encourage experimentation and interdisciplinary collaboration.

Resource limitations represent another significant barrier and demonstrate the unequal conditions under which STEAM education is implemented across the region. Although many STEAM initiatives emphasize the use of innovative technologies such as virtual reality (VR), augmented reality (AR), gamification, and digital learning platforms, the successful adoption of these tools depends heavily on the availability of infrastructure and financial resources (Hakim et al., 2025; Nindiasari et al., 2024; Wannapiroon & Pimdee, 2022). The findings suggest that a digital divide continues to exist between well-resourced institutions and schools operating in rural or underfunded contexts (Naufal et al., 2024; Djam'an, 2025). As a result, the benefits of technology-enhanced STEAM learning may not be distributed equitably across different student populations. This raises important concerns regarding access and educational equity, particularly in developing regions where infrastructure development remains uneven.

The review further highlights policy and curriculum inconsistencies as barriers to sustainable implementation. The absence of clear policy frameworks and standardized guidelines contributes to fragmented practices across different educational levels and countries (Laksmiwati et al., 2023; Anito & Morales, 2019). This finding suggests that STEAM education in Southeast Asia is still undergoing a transition from isolated initiatives toward more institutionalized forms of implementation. Without coherent policy direction, schools and teachers may interpret STEAM differently, leading to variations in curriculum design, instructional practices, and expected learning outcomes. Such inconsistencies may partly explain why successful implementation remains highly dependent on individual educators and institutional contexts rather than system-wide educational reform.

Another important finding concerns the influence of cultural and contextual factors on curriculum implementation. Integrating interdisciplinary and innovative teaching approaches within educational systems that have traditionally emphasized subject compartmentalization can create tensions between established practices and emerging pedagogical expectations (Ha, 2023; Khoiri et al., 2023). While contextualized STEAM approaches offer opportunities for cultural relevance, they also require teachers to negotiate between local educational traditions and contemporary educational reforms. This suggests that successful STEAM implementation requires adaptation to local contexts rather than direct adoption of international models.

Assessment and evaluation challenges further reveal a critical gap within the current STEAM landscape. The findings indicate that educators continue to experience difficulties in measuring complex competencies such as creativity, collaboration, critical thinking, and problem-solving (Sumarni et al., 2025; Ramli et al., 2025). Unlike traditional assessment systems that prioritize subject-specific knowledge acquisition, STEAM education aims to develop interdisciplinary skills that are often more difficult to evaluate objectively. Consequently, the lack of validated assessment frameworks may hinder both the monitoring of student progress and the ability to demonstrate the impact of STEAM initiatives. This issue may also contribute to hesitation among policymakers and educational leaders who require measurable evidence before committing resources to large-scale implementation.

Overall, the findings suggest that barriers to STEAM implementation in Southeast Asia are interconnected rather than independent. Teacher readiness, resource availability, policy support, curriculum alignment, and assessment practices collectively influence the effectiveness of STEAM initiatives. Addressing these challenges therefore requires a systemic approach that moves beyond isolated interventions. Sustainable implementation will likely depend on

coordinated efforts involving educational institutions, policymakers, teacher education providers, and local communities to establish supportive environments that enable meaningful and equitable STEAM integration across different educational levels.

4.3 What opportunities and recommendations emerge from the reviewed studies to strengthen STEAM education in the region?

The findings suggest that opportunities for strengthening STEAM education in Southeast Asia extend beyond the adoption of individual instructional strategies and require a more comprehensive transformation of curriculum design, teacher preparation, technological integration, assessment practices, and policy support. Across the reviewed studies, project-based learning (PjBL), design thinking, and inquiry-based approaches consistently emerged as effective pedagogical models because they align closely with the interdisciplinary objectives of STEAM education (Sumarni et al., 2025; Suryanti et al., 2023; Rahmawati et al., 2025). These approaches provide learners with opportunities to engage in authentic problem-solving activities that integrate knowledge across multiple disciplines. The consistent positive outcomes reported across different educational contexts suggest that active learning approaches may be more compatible with STEAM objectives than traditional content-focused instruction. However, the predominance of short-term intervention studies indicates that further evidence is needed to determine whether these pedagogical benefits can be sustained over time. Nevertheless, the findings support the adoption of modular STEAM curricula that combine PjBL, design thinking, and inquiry-based learning to encourage creativity, collaboration, and scientific literacy (Nguyen et al., 2024; Imamyartha et al., 2024).

Teacher capacity building emerged as another critical opportunity for improving STEAM implementation. The strong emphasis on teacher readiness across many studies suggests that educators remain central to the success of STEAM initiatives (Taibo & Liang, 2022; Pransiska et al., 2025; Laksmiwati et al., 2023). While professional development programmes are increasingly available, the review indicates that effective STEAM implementation requires more than short-term training. Instead, sustained professional learning experiences that include mentoring, collaborative lesson planning, classroom coaching, and reflective practice appear more capable of supporting long-term pedagogical change (Sutama et al., 2020; Tan et al., 2020; Wannapiroon & Pimdee, 2022). This finding implies that educational institutions should shift from viewing professional development as a one-time intervention toward establishing continuous learning ecosystems that support teachers throughout the implementation process.

The growing integration of digital technologies presents substantial opportunities to transform STEAM learning experiences. Mobile learning, augmented reality (AR), virtual reality (VR), artificial intelligence (AI), and computational thinking have demonstrated potential to enhance engagement, conceptual understanding, and problem-solving abilities (Siregar et al., 2023; Hakim et al., 2025; Nindiasari et al., 2024; Relmasira et al., 2023). However, the findings also suggest that technology should not be viewed as an end in itself. The effectiveness of these innovations appears to depend largely on how they are pedagogically integrated into learning environments. Consequently, a pedagogy-first approach is necessary to ensure that technological tools support meaningful learning rather than simply increasing technological exposure. This finding is particularly relevant for Southeast Asian educational systems, where disparities in infrastructure and access may influence the effectiveness of technology-enhanced learning initiatives.

The review also highlights an important opportunity for developing culturally responsive and contextually relevant STEAM education. Unlike many international STEAM models that emphasize universal frameworks, several Southeast Asian studies demonstrated the value of integrating local culture, indigenous knowledge, community practices, and sustainability issues into classroom learning (Ha, 2023; Muzakkir et al., 2024; Sumarni et al., 2025). Such approaches not only promote student engagement but also help ensure that STEAM education remains relevant to local communities and societal needs. The inclusion of environmental literacy, renewable energy, local wisdom, and faith-based perspectives illustrates how STEAM can be adapted to address regional priorities while maintaining interdisciplinary learning goals (Ellianawati et al., 2024; Djam'an, 2025; Rahmawati et al., 2022). This finding suggests that future STEAM initiatives should emphasize localization rather than relying solely on imported educational models.

Another significant opportunity concerns the development of assessment frameworks capable of measuring the complex competencies associated with STEAM education. The findings indicate that assessment remains one of the least developed areas of STEAM implementation despite being essential for monitoring educational effectiveness (Ramli et al., 2025; Worapun & Nuangchalerm, 2024). Traditional assessment systems often prioritize content knowledge, whereas STEAM aims to foster creativity, collaboration, critical thinking, and interdisciplinary problem-solving. Without appropriate assessment mechanisms, it becomes difficult for educators and policymakers to evaluate programme success or justify continued investment. Therefore, future efforts should focus on developing validated and contextually relevant assessment tools that capture the broader learning outcomes associated with STEAM education.

Finally, policy support and educational leadership emerged as critical enabling factors for sustainable STEAM implementation. The findings suggest that successful STEAM initiatives require more than classroom-level innovation; they depend on supportive organizational cultures, institutional commitment, and coherent policy direction (Laksmiwati et al., 2024; Anito & Morales, 2019). Educational leaders play an important role in shaping teacher engagement, allocating resources, and facilitating interdisciplinary collaboration. Furthermore, policy frameworks that promote equity, local relevance, and curriculum flexibility can create conditions that support long-term innovation (Adnan et al., 2023; Belbase et al., 2021). This indicates that strengthening STEAM education should be viewed as a systemic reform effort rather than an isolated instructional initiative.

Overall, the opportunities identified in this review demonstrate that STEAM education in Southeast Asia possesses considerable potential to support educational transformation. However, realizing this potential requires coordinated efforts across curriculum development, teacher education, technology integration, assessment, and policy. The findings suggest that sustainable STEAM implementation will depend not only on adopting innovative practices but also on creating supportive systems that enable these practices to be meaningfully integrated into diverse educational contexts throughout the region.

5. Conclusion

This systematic literature review synthesized findings from 49 studies on STEAM education across six Southeast Asian countries, namely Malaysia, Vietnam, Thailand, Indonesia, and the Philippines. The findings demonstrate that STEAM education has significant potential to enhance students' creativity, collaboration, critical thinking, problem-solving abilities, and technological competencies. Across the reviewed studies, project-based learning, design thinking, technology integration, and culturally responsive approaches emerged as the most prominent strategies for promoting meaningful interdisciplinary learning.

Despite these promising developments, several challenges continue to hinder effective implementation. The most frequently reported barriers include insufficient teacher readiness, limited access to technological and instructional resources, inconsistent curriculum frameworks, and inadequate assessment mechanisms. These challenges suggest that successful STEAM implementation requires coordinated efforts at the pedagogical, institutional, and policy levels.

Based on the findings, three priority recommendations are proposed for policymakers and educational stakeholders. First, greater investment should be directed toward sustained professional development programmes that strengthen teachers' interdisciplinary pedagogical knowledge and confidence in implementing STEAM approaches. Second, curriculum frameworks should be redesigned to incorporate project-based learning, design thinking, and culturally relevant content that reflects local knowledge, heritage, and sustainability issues. Third, governments and educational institutions should improve access to digital technologies, assessment tools, and instructional resources that support equitable STEAM implementation across different educational settings.

Future research should focus on three key areas. First, more longitudinal studies are needed to examine the long-term impact of STEAM education on students' academic achievement, creativity, and career readiness. Second,

comparative cross-country studies within Southeast Asia could provide deeper insights into contextual factors influencing implementation success. Third, future investigations should develop and validate assessment instruments capable of measuring higher-order outcomes such as creativity, collaboration, critical thinking, and interdisciplinary problem-solving. Addressing these research gaps will contribute to a stronger evidence base for guiding STEAM policy and practice in the region.

Overall, STEAM education represents a transformative educational approach that can support the development of future-ready learners. By combining innovative pedagogy, teacher capacity building, technology integration, cultural contextualization, and supportive policy environments, Southeast Asian education systems can strengthen the quality, relevance, and sustainability of STEAM education for future generations.

Declarations

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Competing Interests
None.

Ethical Approval
This study did not require formal ethical approval as it did not involve human participants, surveys, interviews, or the collection of any personal or sensitive data. The review relied exclusively on published secondary sources obtained from academic journals and online databases. In accordance with institutional research guidelines, studies based solely on publicly accessible literature and secondary data are classified as low-risk and are therefore exempt from ethics review. As such, the procedures undertaken in this systematic review comply fully with ethical standards for non-human-subject research.

Author's Contribution
Author[1]: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft preparation, Writing – review and editing.
Author[2]: Supervision, Investigation, Validation, Guidance throughout the research process.
Author[3]: Supervision, Investigation, Validation, Guidance throughout the research process.

Data availability
All data analyzed in this systematic review were obtained from secondary sources available in the Scopus and Web of Science (WoS) databases. The search, retrieval, and screening procedures are fully described in the Method section of this paper. As this study relied exclusively on published literature indexed in Scopus and WoS, no additional datasets were generated. The bibliographic records retrieved from these databases can be accessed directly through their respective platforms using the search strings provided in this study.

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