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ORIGINAL ARTICLE

# STEM Education in ASEAN Countries: Practices and Way Forward

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## ABSTRACT

Several countries have developed STEM education to boost global competitiveness. Studies on the implementation of STEM have revealed that educators and curriculum developers employ a variety of frameworks. These variances highlight the need for educators in the ASEAN community to have a shared understanding of STEM implementation to guide their teaching practice. We analyzed the literature on STEM implementation to create a knowledge base that would better guide policymakers and educators. The initial literature search identified 988 studies, but only 11 articles met the inclusion criteria for selection. We report on STEM education practices in ASEAN countries, their implementation status, and their impact on learners. We also discuss the geographical and practical gaps and highlight critical areas for future inquiries.

**KEY WORDS:** STEM curriculum; STEM implementation; STEM approaches; STEM education; ASEAN education

## INTRODUCTION

Education is vital for a country's economic growth, social progress, and innovation, turning knowledge into an important resource. As a result, creating a smarter nation is challenging for many countries because it raises the need for education. Therefore, schools are pushing STEM education into their frameworks to enhance students' learning experiences and equip them with skills necessary for globalization (Stehle and Peters-Burton, 2019). STEM education is a holistic approach where these disciplines are taught in a way that highlights their overlaps and how they work together to solve real-world problems (Dare et al., 2021). This interdisciplinary nature of STEM prepares students for complex challenges and fosters critical skills needed for the 21st century.

Countries subject their students to standardized examinations such as the TIMSS and PISA to assess their educational systems, further informing policy and curriculum development. The TIMSS 2019 results in mathematics and science indicate that most East Asian countries, such as Singapore and Korea, were the top performers in science by substantial margins in the fourth and eighth grades (Mullis et al., 2020). Out of 64 countries participating in the TIMSS 2019 survey, only three participated from the ASEAN region, Malaysia, the Philippines, and Singapore. TIMMS 2019 results also noted that several nations are training their students to minimal competency of more than 92% in fourth grade and 85% in eighth grade, which suggests students have inadequate comprehension of scientific ideas and mastery of core science facts (Mullis et al., 2020). This situation reflects some problems and challenges in implementing the educational system.

In ASEAN countries, several challenges hinder effective STEM education. Teachers raised issues about the need for appropriate textbooks for reference and instructional materials, insufficient classroom materials, laboratory chemicals and equipment, and a shortage of science teachers (Pareek, 2019). These challenges are compounded by the crucial role that qualified and competent teachers play in the success of STEM education, as they directly influence students' scientific literacy levels and ability to grasp complex scientific concepts (Chen et al., 2021; Schiffl, 2020). The need for more skilled teachers and adequate resources has likely contributed to poor performance in the 2019 TIMSS results for some ASEAN countries.

STEM education is designed to integrate science, technology, engineering, and mathematics, providing students with interdisciplinary knowledge and skills to solve real-world problems (Ramli and Talib, 2017; Moore et al., 2020). Effective implementation often involves project-based learning, team contests, and interactions with STEM professionals (Sullivan and Bers, 2018; Teo et al., 2017). Industrialized countries such as the United States, England, the Netherlands, and Australia have extensively researched and invested in STEM education, focusing on its implementation, usage, and impact on student learning (Özkaya, 2019). In contrast, the ASEAN region has conducted limited academic research in STEM education, with much of the scholarly focus on the region's economy, politics, security, and trade development (Ha et al., 2020). Globally, challenges in standardizing STEM curricula have hindered its widespread adoption, with diverse interpretations and limited alignment to research-based practices (Martín-Páez et al., 2019; Roehrig et al., 2021). These challenges are pronounced in ASEAN, where a lack of a unified STEM education framework and a general STEM concept has made classroom implementation difficult (Mpofu, 2019). Addressing these gaps is essential for ASEAN countries, given their diverse economic and cultural contexts, to fully realize the potential of STEM education in fostering innovation and development.

Our study explored and outlined various strategies employed in STEM education implementation, the current state and level of development of STEM education initiatives, and the effectiveness of STEM education in enhancing learning outcomes, fostering higher-order thinking skills (HOTS), and promoting motivation among students across the ASEAN nations from 2015 to 2020. This study highlights effective practices, common challenges, and areas for improving STEM education. The study answers the following research questions:

1. What are the different approaches to implementing STEM education in ASEAN countries?
2. What is the status of STEM education in the ASEAN countries?
3. Does STEM education successfully boost learning outcomes, HOTS, and motivation in the ASEAN countries?

# METHODOLOGY

## Research Design

This review combines diverse studies to explore STEM education in the ASEAN region and its role in improving outcomes and developing HOTS in students. In conducting the review, we incorporated key elements of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021). Specifically, we followed four primary steps:

1. Identifying research literature through database searches
2. Screening articles using inclusion and exclusion criteria
3. Assessing full-text articles for eligibility
4. Coding and reporting the final set of articles included in the review.

However, we did not fully implement the complete PRISMA checklist. We did not rely on Scopus, ProQuest, or Web of Science as primary databases. Instead, we utilized Google Scholar through Harzing's Publish or Perish software, which included scholarly and non-scholarly materials. This approach was intentionally adopted to exhaust all possible articles related to STEM implementation and frameworks in ASEAN countries. Our goal was to avoid limiting the dataset and to develop a comprehensive understanding of the research topic through diverse and inclusive sources.

## Data Sources and Literature Search

We accessed the Google Scholar database sources with a maximum of 1000 (n) results through Harzing's Publish or Perish software. This database thoroughly covers the literature on STEM education and various fields. This study employed a search strategy that evolved over multiple rounds to explore topics beyond the initial research questions. As the team became more familiar with the literature, the basic search phrases were refined and finalized into the search string in Table 1.

The initial search retrieved 988 items from Google Scholar using Harzing's Publish or Perish software. The "snowball" method expanded the dataset, examining citations within relevant publications (Hepplestone et al., 2011). This method led to the identification of eight additional articles. Additional databases, including ERIC, ResearchGate, ProQuest, and Scopus, were consulted to find further relevant studies. Forward citation searching was conducted using the search terms listed in Table 1 to identify pertinent articles of each database, then click the "Cited by" link to retrieve articles that cited them. Backward citation searching was also done, which involved manually reviewing the reference lists of relevant articles to identify additional cited works. The Scopus search identified three articles, and ResearchGate also yielded three articles. However, searches in ERIC and ProQuest did not produce any relevant results. In addition, two more articles were discovered through backward citation searching within Google Scholar.

## Study Selection and Accessing Full Articles

Figure 1 depicts the multistage screening process used to evaluate and select studies identified in the search. During the identification phase, 988 records were retrieved using Harzing's Publish or Perish software to search Google Scholar. In addition, eight more studies were identified through citation searching in other databases. Nine duplicates were identified in the Google Scholar results and subsequently removed.

The screening phase has two distinct steps. First, the titles and abstracts of the 987 articles were reviewed to identify those specifically mentioning STEM implementation and STEM frameworks. The initial screening resulted in 41 articles for further evaluation.

In the second step, the full texts of these 41 articles were retrieved. These articles were then assessed against the eligibility criteria. The inclusion criteria required that studies be conducted in ASEAN countries, written in English, and published as peer-reviewed, indexed, open-access journal articles, conference papers, or structured literature reviews. Papers that did not address STEM education implementation (n = 30) were excluded from the final analysis. In addition, articles were excluded if their full text was available only in another language, even if their abstracts were in English.

Following a rigorous shortlisting and consensus-building process, 11 articles were included for qualitative evidence synthesis. To ensure comprehensiveness (Cronin and George, 2020) and provide a holistic perspective (Blakeman, 2019), we purposefully broadened the criteria to integrate diverse and compelling viewpoints on STEM education in the ASEAN region.

## Coding and Reporting the Results

We analyzed the studies by ordering, coding, categorizing, and summarizing into a unified and integrated conclusion about

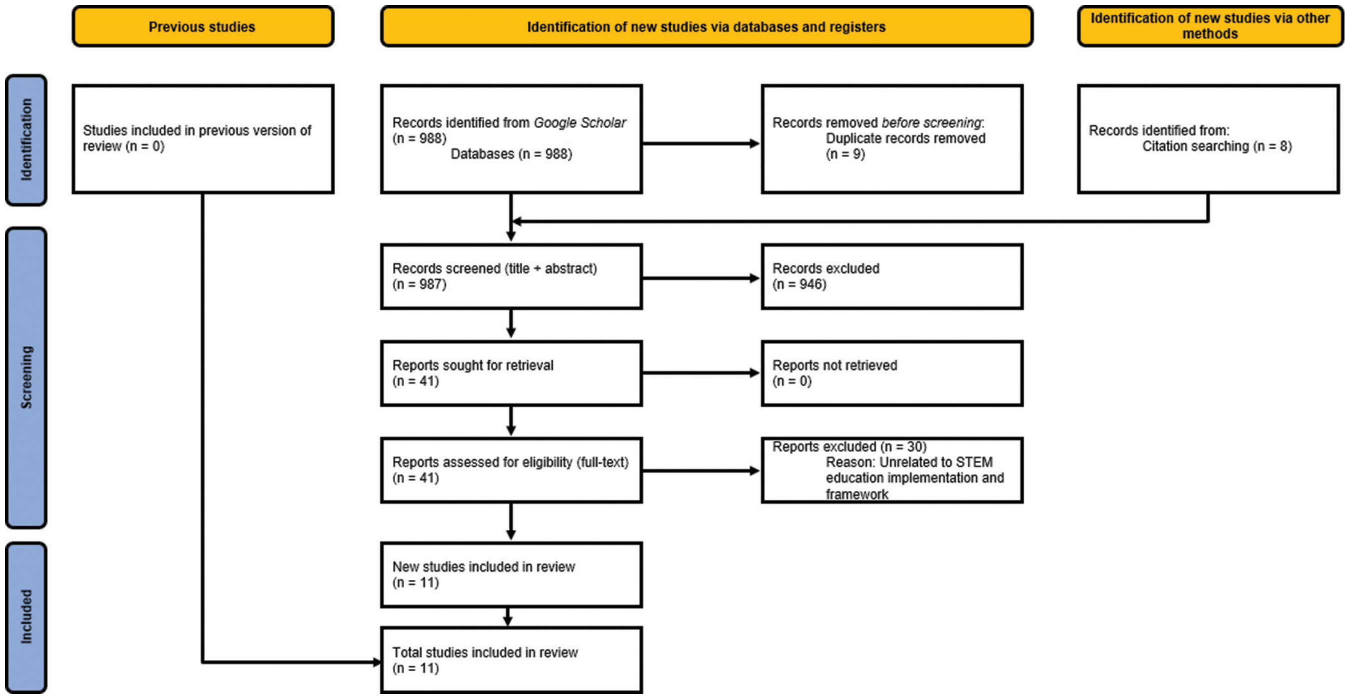


**Figure 1:** Literature review flow diagram

**Table 1: Search strategy terms**

| Database | Search terms or keywords | Number |
|---|---|---|
| Google Scholar | STEM Education STEM Implementation STEM Integration ASEAN Countries Brunei Cambodia Indonesia Laos Malaysia Myanmar Philippines Singapore Thailand Vietnam | 988 |

the research problem and identifying the patterns and themes (Cooper, 2015). In addition, we utilized the data analysis elements based on Patton (2002).

# RESULTS

This section presents the results of our integrative literature review following the order of our research questions.

After screening, the characteristics of the included studies are summarized in Table 2. Only Indonesia (n = 3), Philippines (n = 2), Malaysia (n = 2), Singapore (n = 2), Cambodia (n = 1), and Thailand (n = 1) conducted studies related to STEM education.

After conducting a rigorous integrative review of the selected 11 research articles, we offer the following significant themes for each of the three research questions to lay down the implementation of STEM education in ASEAN countries.

## What Are the Different Approaches to Implementing STEM Education in ASEAN Countries?

### *Contextualized STEM education implementation*

STEM education has already been implemented using various methods across ASEAN countries.

Among the selected papers were three studies from Indonesia that reported on integrating STEM education into their curriculum. Indonesia's curriculum reform was created with the demands of the 21st century, and it is now working toward incorporating STEM education into its curriculum framework. The Indonesian government is encouraging teachers to receive training on the "hows" of STEM implementation to integrate it into the curriculum along with their curriculum reform (Suwarma and Kumano, 2019; Winangun and Kurniawan, 2019). Arlinwibowo et al. (2020) also revealed local variances in STEM implementation in Indonesian schools.

In the Philippines, STEM education is embedded in the SHS K to 12 curricula as one of the academic tracks offered. The STEM subjects are grouped into two categories: core and specialized. The seamless and integrated learning in the form of spiral progression is one of the curriculum's notable aspects (Tupas and Matsuura, 2019). The spiral approach in science and mathematics offers concepts and competencies in all fields of science, including biology, chemistry, physics, and earth science, with progressive complexity levels from one grade level to the next, providing a realistic path to a more excellent grasp of basic concepts (Antipolo and Danilo, 2021). Meanwhile, the Philippine Commission on Higher Education extended STEM to STEAM in higher education institutions offering STEM courses, where A symbolizes agri-fisheries courses (Sarmiento et al., 2020) as agriculture and fishing are the principal sources of income for Filipinos and contribute considerably to the economy.

Singapore's education system is geared toward the STEM approach, giving elementary education a stronger foundation

**Table 2: Summary of studies**

| Author | Country | RQ1: What are the different approaches to implementing STEM education in ASEAN countries? | RQ2: What is the status of STEM education in the ASEAN countries? | RQ3: Does STEM education successfully boost learning outcomes, HOTS, and motivation in the ASEAN countries? |
|---|---|---|---|---|
| Arlinwibowo et al. (2020) | Indonesia | There are local variations of STEM implementation.<br>STEM education is implemented through project-based learning.<br>The principal is the most influential person in STEM implementation. | The current state of the Indonesian curriculum is fragmented between subjects. Thus, there must be a specific strategy for each school in the implementation of STEM. | No information provided |
| Bahrum et al. (2017) | Malaysia | STEM implementation is focused on inquiry-based learning, problem-solving, contextual learning, collaborative learning, and project-based learning. | STEM education in Malaysia is very new and there have been serious efforts by the government and researchers toward the development of STEM education. Combining elements of "art" into the disciplines in STEM to STEAM to strengthen STEM education. | No information was provided. |
| Ramli and Talib (2017) | Malaysia | Malaysia implements STEM education that is integrated with the applicable curriculum.<br>STEM is implemented in schools through science projects. They are using science facts, calculating it with mathematics formula, finding information using technology, designing, and building the model. | There were six major barriers appointed by the participants which are motivation, syllabus, skill (training), inadequate facilities, student involvement, and responsive environment. | Students indicate high interest in STEM projects as seen through voluntarily staying after school to finish the project, use of their own money, and using their creativity to build and design the project. |
| Sarmiento et al. (2020) | Philippines | There is an integration of "agri-fisheries" instead of the usual "arts" in STEM education. There were established assessment practices in monitoring and evaluating students' learning and academic progress which describes how STEAM teachers collaborate, reflect, and utilize real-life situations, stakeholders' participation, role-playing, simulations, and technology-enhanced tools and techniques for the different purposes of assessment. | The implementation of STEAM education in higher education institutions in the Philippines is still in its nascent stages.<br>There are no assessment indicators for higher STEAM education that serve as a blueprint for STEAM teachers in conducting assessments, which explains the broad diversity in practice. | No information was provided. |
| Sritrakul (2018) | Thailand | The government has assigned IPST as the main department to impel STEM education in which regional STEM centers act as the main office for STEM network schools. | STEM education in Thailand has not fully developed. | The students had limited time to do STEM activities since they had to spend most of the time on other subjects. |
| Sovansophal and Shimizu (2020) | Cambodia | The Ministry of Education, Youth and Sports (MoEYS) developed the New Generation School which aims to increase skill levels in STEM subjects at upper secondary school through intensive capacity building in educational technology and STEM and problem-based learning methodologies. The teaching hours for STEM subjects have been increased to 6 and 4 h/week. MoEYS suspends licenses to open new non-STEM programs and courses to encourage higher education institutions to offer STEM courses.<br>Holding STEM festivals to attract students to take STEM courses. | More students prefer to enroll in the science track than in social science in the upper secondary level. However, there is a decline in the number of graduates in higher education in the STEM fields.<br>There is a lack of manpower in STEM fields as well as educators in the STEM fields, thus compromising the quality of STEM education. | There is lower interest and attitudes of the students toward STEM subjects, and it is linked to the lack of qualified teachers for science and mathematics at upper secondary schools and poor teaching and learning facilities. |
| Suwarma and Kumano (2019) | Indonesia | STEM education is not embedded in the curriculum reform. However, teachers are encouraged to integrate STEM into the curriculum. | STEM education is still new.<br>Further training in STEM content and its applications is still needed as implementation continues. | No information was provided. |

(*Contd...*)

**Table 2: (*Continued*)**

| Author | Country | RQ1: What are the different approaches to implementing STEM education in ASEAN countries? | RQ2: What is the status of STEM education in the ASEAN countries? | RQ3: Does STEM education successfully boost learning outcomes, HOTS, and motivation in the ASEAN countries? |
|---|---|---|---|---|
| Tawbush et al. (2020) | Singapore | There are STEM schools in Singapore.<br>STEM education focuses on student-centered instruction.<br>STEM education is practiced in Singapore using computers, hands-on real-world experiences, model-eliciting activities, and ICT. | STEM schools are present in Singapore. | No information was provided. |
| Tupas and Matsuura (2019) | Philippines | The senior high school (SHS) STEM curriculum is embedded in the Kindergarten to Grade 12 (K to 12) curricula but not all schools offer STEM strands.<br>The subjects are divided into two; core and specialized.<br>STEM subjects have a spiral progression of topics.<br>Some subjects are research-based. | The K to 12 curriculum is new, so close monitoring and evaluation of STEM education is advised.<br>There is a lack of time management for teachers to hold classes, limited science textbooks and classrooms, and unavailability of the laboratory for hands-on activities that need proper attention by concerned authorities. | The spiral concepts from junior high school to senior high school enable learning interest in STEM subjects as they already have basic knowledge of the subjects.<br>Not all students enrolled in SHS-STEM track want science-related courses in college. |
| Worsham et al. (2016) | Singapore | Parents are much more involved in their children's education.<br>Government policy encourages students to enter STEM fields through the creation of the Ministry of Science and Technology and a high percentage of government spending on education.<br>The education system also fosters interest in STEM and helps prepare students in the subjects at the level of their capability.<br>The curriculum provides a better science and math foundation in elementary years. | Singapore's education system is already tailored in STEM education. Their system focused on literacy, quality of labor, creativity, and innovation. | Singapore has a higher percentage of students who graduate from universities with STEM degrees. |
| Winangun and Kurniawan (2019) | Indonesia | Since STEM education is not embedded in the curriculum framework, teachers used varied ways to implement STEM in their classes. | Some teachers have been trained to implement STEM education in their curriculum. | No information was provided. |

in science and mathematics (Worsham et al., 2016). STEM schools are also found in Singapore, where students can get excellent knowledge and competencies to become globally competent (Tawbush et al., 2020). Aside from its curriculum, the Singaporean government encourages students to pursue STEM careers by establishing the Ministry of Science and Technology and allocating much government funding to education (Worsham et al., 2016).

The integration of STEM education in the Malaysian educational context depends on how teachers apply it in their classes since STEM still needs to be fully embedded in their education system (Ramli and Talib, 2017). Teachers are urged to use STEM teaching methodologies to generate students with science literacy qualified for STEM-related career opportunities (Bahrum et al., 2017). Meanwhile, Cambodia's MoEYS has stepped up efforts to incorporate STEM education into the country's present educational environment by training teachers in STEM instructional strategies and increasing allotted hours for STEM subjects (Sovansophal and Shimizu, 2020). Furthermore, the MoEYS suspended the opening of non-STEM courses and organized STEM festivals to entice more students to STEM courses (Sovansophal and Shimizu, 2020).

Conversely, the Thai government established an institute to promote STEM education in the country's STEM network schools (Sritrakul, 2018). The Ministry of Education in Thailand has organized a policy as STEM implementation develops, so schools allot time for STEM activities. Based on the drafted framework, teachers are encouraged to assign one project per semester to their students (Sritrakul, 2018).

### *Strategies in STEM teaching*

Several papers reported different teaching strategies that are used in implementing STEM.

In the Philippines, several research subjects are present in the K to 12 curricula (Tupas and Matsuura, 2019). Sarmiento et al. (2020) showcased best practices in their study that can serve as a benchmark to nurture quality assessment delivery and STEM learning. Role-playing and simulations using authentic and real-life situations and technology-enhanced tools are established assessment practices for monitoring and evaluating students' learning and academic progress.

In Malaysia, STEM implementation focuses on inquiry-based, problem-solving, contextual, collaborative, and project-based learning (Bahrum et al., 2017). Malaysian students are encouraged to use scientific facts, calculate them with mathematical formulas, find information using technology, and design and build models (Ramli and Talib, 2017).

In Singapore, STEM teaching practices focus more on student-centered STEM teaching practices such as using computers, hands-on, real-world experiences, model-eliciting activities, and ICT (Tawbush et al., 2020). Play is considered a STEM activity in primary education (Sullivan and Bers, 2018).

Meanwhile, STEM education in Thailand adopts learning approaches such as problem-based learning, project-based learning, and active learning (Sritrakul, 2018). Learners' access to group communication and teamwork in a project-based learning activity are just some of the STEM activities applied in the classroom.

## What is the Status of STEM Education in the ASEAN Countries?

### *Achievement and progress of STEM implementation*

Singapore has established STEM schools (Tawbush et al., 2020). Adopting a student-centered teaching approach has been crucial in successfully implementing STEM education in Singapore (Tawbush et al., 2020; Worsham et al., 2016). Effective planning, program implementation, monitoring, and evaluation have contributed to the outstanding performance of Singaporean students, who have outperformed the OECD average in reading, mathematics, and science on international benchmark tests like PISA and TIMSS (Worsham et al., 2016).

In Malaysia, the implementation of STEM education began in 2017 as part of the Secondary School Standard Curriculum, aimed at improving students' performance in international education standards. The Malaysian government prepares its children for the 21st century and raises public and parental expectations of education policy by strengthening STEM education. The elements of "arts" were incorporated into STEM, creating STEAM (Bahrum et al., 2017) as it fosters creativity, critical thinking, and innovation. While STEAM is gaining traction in educational discourse, it remains a developing concept, and its adoption among science educators has yet to be widespread.

The Thai government views education as the cornerstone for producing competent individuals and building a strong society based on quality and moral values. Thai schools have shown interest in STEM education networks; however, the implementation of STEM education in Thailand still needs to be completed (Sritrakul, 2018). Implementing STEM education in Northern Thailand faces limited resources and budgets, insufficient teacher training, inconsistent administrative support, and a lack of parental understanding and involvement. In addition, disparities among schools, inefficient policy coordination, and time constraints hinder the effective integration of STEM initiatives, highlighting the need for improved resource allocation, policy execution, and stakeholder engagement.

STEM education in Indonesia is relatively new (Arlinwibowo et al., 2020; Suwarma and Kumano, 2019). The current curriculum in Indonesia is fragmented, which makes it necessary to have a specific strategy for each school to implement STEM education (Arlinwibowo et al., 2020).

The integration of STEM education in the Philippines only allowed some students to choose to enroll in the STEM strand (Tupas and Matsuura, 2019). In higher education institutions, STEM education is extended to STEAM, which aims to incorporate agriculture into the educational system since most Filipinos rely on it for their livelihood (Sarmiento et al., 2020).

Cambodia's MoEYS oversees and improves the education, youth, and sports sectors to meet the country's socioeconomic and cultural development needs, particularly emphasizing the importance of implementing STEM education. Despite mentioning STEM schools, integrating STEM education into Cambodia's national curriculum framework remains incomplete (Sovansophal and Shimizu, 2020). Challenges include a lack of competent and qualified teachers and facilities, low enrollment in STEM fields, negative perceptions of STEM careers, gender disparity, and poor academic achievement in science and mathematics. These issues highlight the need for systemic reforms to improve infrastructure, teacher training, and public attitudes toward STEM to meet the demands of a knowledge-based economy.

### *Challenges in STEM implementation*

Several problems and challenges have been reported, especially for those countries that have reported STEM implementation but are still in the early stages.

Insufficient knowledge of content integration and methodologies has led to challenges in implementing STEM education among Indonesian teachers, resulting in the continued treatment of science, engineering, technology, and mathematics as individual subjects (Arlinwibowo et al., 2020). There are six significant barriers to STEM implementation in Malaysia: motivation, lengthy syllabi, time constraints, inadequate facilities, student involvement, and an unresponsive environment (Ramli and Talib, 2017). There are also challenges in STEM implementation in the Philippines, including a lack of time management for teachers, limited resources, and inadequate laboratory access (Tupas and Matsuura, 2019). There is a need for more STEM education specialists in Thailand (Sritrakul, 2018) and Cambodia (Sovansophal and Shimizu, 2020).

### Does STEM Education Successfully Boost Learning Outcomes, HOTS, and Motivation in the ASEAN Countries?

#### *Impacts of STEM education on learning outcomes, HOTS, and motivation*

The Philippines, Indonesia, Cambodia, Thailand, and Malaysia reported how STEM education improves learning outcomes, HOTS, and motivation among the 10 ASEAN member states.

STEM education in the Philippines features HOTS and critical thinking skills (Sarmiento et al., 2020). With this, students exposed to STEM learning can think critically in solving real-life problems. Indonesian students exposed to contextual, problem-based learning resulted in higher learning outcomes (Arlinwibowo et al., 2020). Project-based and inquiry-based learning promotes student learning in Cambodia (Sovansophal and Shimizu, 2020). Some Thai students became more imaginative and innovative since they were allowed to solve real-world problems through STEM activities (Sritrakul, 2018).

Further, STEM activities increased students' learning enthusiasm. STEM activities appeal to Filipino senior high school students because teachers allow them to immerse themselves in the workplace and participate in hands-on activities (Tupas and Matsuura, 2019). Malaysian teachers observed a strong student interest in STEM projects after exposure to STEM lessons and activities (Ramli and Talib, 2017; Bahrum et al., 2017). Exposing Cambodian students to more exciting science and mathematics lessons cultivates their initial interests in science and mathematics (Sovansophal and Shimizu, 2020).

#### *Enablers for successful STEM education*

The enablers contribute to the success of STEM education implementation. These enablers are groups vital in establishing quality education and a prosperous economy, including the government, education system, culture, and family. These groups support education that enables the successful implementation of STEM learning.

The government is one component that significantly impacts the performance of STEM education in a country. In Cambodia, the government encourages student interest and public attitudes toward STEM in higher education through initiatives such as the STEM festival (Sovansophal and Shimizu, 2020). Furthermore, the Singaporean educational system emphasizes encouraging interest and assisting students at their level of competence (Worsham et al., 2016). Students preparing to study STEM courses are exposed to STEM subjects in lower years to prepare them for college challenges. Singaporean students receive proper career choices as they prepare themselves by pursuing various classes.

The education system also depends on the teachers, the forerunners in implementing education. Teachers using technology-enhanced assessments helped teach Filipino STEM students (Sarmiento et al., 2020). Furthermore, Singaporean teachers using computers and robotics in a one-on-one student-to-device ratio let the students experience hands-on, real-world simulations essential in developing STEM competencies (Tawbush et al., 2020).

Culture and parental support also influence STEM implementation. Most Singaporeans value education over other factors (Worsham et al., 2016). Singaporean students achieve higher than other ASEAN students since it has become part of their culture that an individual's success is also the family's success, making Singaporean parents directly involved in their child's education. Parental involvement in STEM education encourages Singaporean students to improve their skills through exposure to STEM activities and competitions. Singaporean families reported using a math tutor (Worsham et al., 2020) for remediation and learning reinforcement.

## DISCUSSIONS

Based on the findings, we highlight critical areas that significantly contribute to our attempt to develop a coherent knowledge base about STEM education implementation in the ASEAN countries.

First, there is contextualized implementation of STEM education. Each country has integrated STEM education that suits its educational and societal context. Singapore has a well-established implementation of STEM education in its national curriculum, emphasizing science and mathematics during elementary school (Worsham et al., 2016; Tawbush et al., 2020). Other countries such as the Philippines, Indonesia, Malaysia, Cambodia, and Thailand are at varying stages of full integration. For example, the Philippines has embedded STEM education in its national curriculum as one of the tracks offered in its K to 12 curricula (Tupas and Matsuura, 2019; Sarmiento et al., 2020).

Meanwhile, Thailand (Sritrakul, 2018), Cambodia (Sovansophal and Shimizu, 2020), and Malaysia (Ramli and Talib, 2017; Bahrum et al., 2017) have instituted functional units which are specialized departments established at a regional or national level to oversee and support STEM education implementation in schools. This mechanism ensures the delivery of the required resources to the implementing units, as adding this function to the teachers would burden them and negatively affect instructional quality. The implementing units refer to the schools directly responsible for executing classroom STEM education programs. Creating support systems for STEM initiatives is crucial for long-term global success (Kleinschmit et al., 2023). This approach shows a strong commitment to high-quality STEM teaching and providing access to STEM resources and opportunities.

Several educational policy suggestions could be drawn from these results. For countries still fully integrating STEM into their national curriculum frameworks, policymakers could consider allocating resources to provide consistent professional development opportunities for teachers and foster collaboration from other countries to emulate best practices. Future studies on examining the impact of resource allocation on the quality and accessibility of STEM education and identifying strategies for optimizing resource utilization are recommended. The role and effectiveness of functional units in improving the quality of STEM instruction and supporting teachers in delivering STEM education could also be explored.

Second, the ASEAN countries have varying levels of success in implementing STEM education. Providing the required resources for STEM education advances teachers' and learners' interest in achieving quality education. Moreover, promoting professional development among STEM teachers is also critical in successful STEM implementation. The available resources of the developed countries are their edge over the developing countries in forwarding STEM education. Among the articles included, Singapore emerges as the leader in the Southeast Asian region, as shown by the excellent performance of its students in standardized assessments (Worsham et al., 2016; Tawbush et al., 2020).

On the other hand, developing nations in the ASEAN region, including the Philippines, Indonesia, Malaysia, Cambodia, and Thailand, encounter several challenges in implementing STEM education, primarily due to limited resources, inadequate government support, cultural attitudes toward STEM education, and a shortage of qualified teachers (Tupas and Matsuura, 2019; Sarmiento et al., 2020; Suwarma and Kumano, 2019; Winangun and Kurniawan, 2019; Arlinwibowo et al., 2020; Ramli and Talib, 2017; Bahrum et al., 2017; Sovansophal and Shimizu, 2020; Sritrakul, 2018). Developing countries face challenges that make it hard to support STEM education, unlike developed countries with more resources.

Several best practices from the global context should be considered to address the challenges STEM teachers face in the ASEAN region. In Singapore, teachers benefit from continuous training in pedagogy, interdisciplinary teaching, and technology integration (Chai, 2019; Worsham et al., 2016; Tawbush et al., 2020). This model underscores teachers' pivotal role in STEM education success and should be emulated by other ASEAN countries. Many ASEAN teachers are trained in specific disciplines and feel unprepared to effectively teach or integrate content from other fields. Training teachers on interdisciplinary (Wu et al., 2024) and transdisciplinary (Takeuchi et al., 2020) teaching methods could be considered to enrich STEM education by making it more relevant, engaging, and applicable to real-world problems. Studies such as equipping teachers with skills to use simulation tools, online platforms, and virtual laboratories proved to effectively enhance the learning of STEM students, especially in the evolving educational landscape (Kang and Seo, 2021). Studies have also shown that collaboration and partnerships between schools, local industries, universities, and government agencies significantly enhance STEM education (Murphy et al., 2019). ASEAN countries could adopt these approaches to improve their levels of success in STEM education programs.

Third, the literature reported that STEM education improves learning outcomes (Arlinwibowo et al., 2020; Sovansophal and Shimizu, 2020; Bahrum et al., 2017), learners' HOTS (Sarmiento et al., 2020), and motivation (Tupas and Matsuura, 2019; Bahrum et al., 2017; Sovansophal and Shimizu, 2020). The measures of success of STEM instruction largely leaned toward learners' acquisition of 21$^{st}$-century skills. In addition, the successful implementation of STEM education will only prosper with the help of the enablers, such as the government, education system, culture, and family. These enablers contribute their capacities and authority to successfully implementing STEM learning. However, it is evident from the limited number of reviewed papers that only 11 studies have been conducted, which only comprehensively represent some ASEAN countries. This data shows a limited understanding of how STEM education affects student learning. We need more long-term studies to explore the following: the effects of STEM education on learning, how government policies and programs influence this education, the support from different stakeholders, and the role of parental involvement in promoting STEM education.

Fourth, our study reveals substantial geographical gaps. Among the 11 studies analyzed, 27% were conducted in Indonesia, 18% in the Philippines, 18% in Malaysia, 18% in Singapore, 9% in Cambodia, and 10% in Thailand. Not all ASEAN countries have researched their implementation of STEM education. We need more studies from other ASEAN countries to see contextual and policy influences in this area of inquiry.

## CONCLUSION

Our study aimed to synthesize studies that report STEM education implementation in the ASEAN region. Using the PRISMA method, we accessed 11 studies and reviewed them to answer our three research questions. The literature offered different approaches and statuses to implementing STEM education. We also reported several challenges encountered by teachers in STEM implementation. The few studies reported limited our attempt to develop a comprehensive knowledge base on STEM implementation among the ASEAN countries. Our study highlights geographical and practical gaps. Furthermore, the emerging knowledge base relating to this inquiry presents opportunities for future research, including engaging students, supporting teachers, government policies, and parental support.

We acknowledge some limitations of our research. First, our data collection was restricted to Google Scholar publications. While we chose this database for their high-quality indexing and English-language content accessible to a global audience, we recognize that there may be other relevant papers that were not included in our analysis. In addition, we focused exclusively on peer-reviewed articles published between 2015 and 2020. This criterion resulted in our review omitting printed books, book chapters, and articles that discuss STEM implementation in the ASEAN region beyond our specified timeframe.

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