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STEM Learning in Higher Education: A Comparative Study of Science Curriculum in Singapore and Indonesia

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A R T I C L E I N F O

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A B S T R A C T

This study aims to compare STEM education in higher education institutions in Indonesia and Singapore. This research is a systematic literature review with a PRISMA approach. Document searches were conducted using the PoP application in the Google Scholar database. Documents were analyzed from 2020-2024, resulting in 500 documents from the Google Scholar database. Further analysis based on research focus yielded 40 relevant documents. The analysis results show that STEM education in higher education institutions in Indonesia and Singapore has similarities and differences in terms of objectives, aspects, and implementation. The goal of STEM education is directed towards enhancing individual skills to face challenges and meet the demands of the workforce related to 21st-century skills. STEM education in Singapore and Indonesia includes similar aspects, such as support from government and non-government institutions, teaching aspects related to the integration of teaching with other learning models/techniques, efficacy aspects in terms of educators' confidence in their ability to implement STEM, and material aspects concerning the availability of facilities that support learning. The implementation of STEM education in Singapore and Indonesia has been optimally carried out by educators and students through clear learning frameworks and the integration of courses with STEM

INTRODUCTION

The curriculum is a national policy that has a significant impact on the quality of education (Winoto, 2022). Changes in the curriculum provide opportunities for stakeholders to design a curriculum that is appropriate and meets global demands (Jannah, 2023; Nevenglosky et al., 2019). Especially the demands of the 21st century, which emphasize the 4C skills (creativity and innovation, critical thinking and problem-solving, communication, collaboration), technology and information skills, and life and career skills (Malik, 2018; Partnership for 21st Century Learning, 2016; Stehle & Peters-Burton, 2019). These abilities and skills form the foundation for a country in developing its curriculum. Additionally, the results of surveys conducted by PISA are one benchmark for a country to have a good quality education. To provide quality education globally, many countries align their education curricula and indicators with PISA (Syarif et al., 2023).

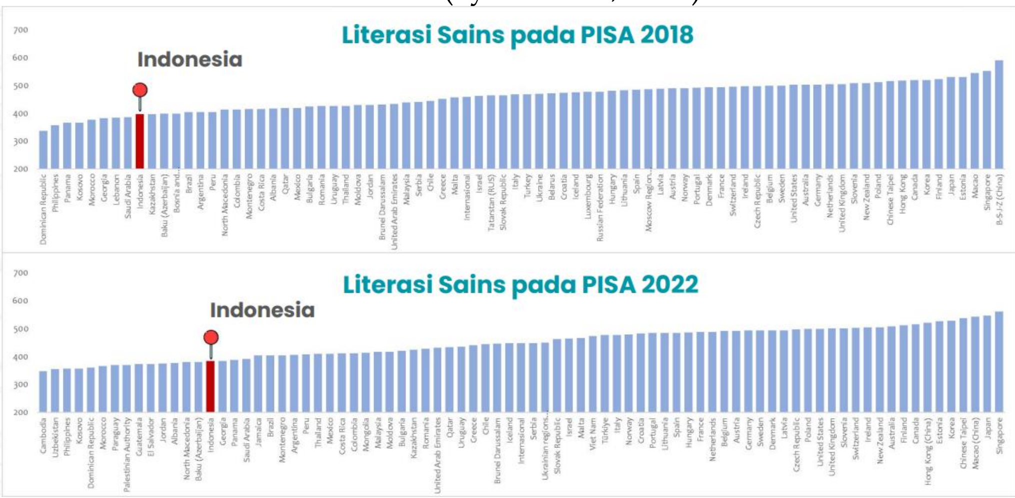

Figure 1. Indonesia's Ranking in Science Based on the PISA Survey
Source: (Kemdikbudristek, 2023)

Figure 1 shows that Indonesia's ranking in science based on the PISA survey results has improved. However, the science literacy score in 2022 decreased by 13 points from 396 (in 2018) to 383. This decline is also nearly equivalent to the international average, with about 52% of PISA countries in 2022 experiencing a drop in science literacy scores compared to 2018 scores (Kemdikbudristek, 2023). On the other hand, Singapore, which holds the top PISA ranking, scored 561 in science literacy, an increase of 10 points from the previous year's 551 (OECD, 2023).

STEM education (Science, Technology, Engineering, Mathematics) supports the development of science literacy in both Indonesia and Singapore. STEM education is becoming increasingly important in the field of education and has garnered widespread attention from educators and stakeholders. Especially with the demands of the times, STEM education serves as an alternative for training 21st-century skills such as critical thinking, creativity, and technology (Li et al., 2016; Wahono et al., 2020). Through STEM, students can actualize concepts in real life (Estapa & Tank, 2017; Sutaphan & Yuenyong, 2019) and this also impacts students' literacy skills (Susanta et al., 2023). Analysis over a decade shows that STEM education has globally increased (Fatimah et al., 2024). Many countries are preparing their citizens to understand and master STEM for use in an ever-evolving modern life (Pimthong & Williams, 2018).

The rising interest in STEM education in science learning offers an interesting perspective to compare STEM education in Indonesia and Singapore. Discussing further the comparison of science curricula between the two countries is important to understand the broader context of the educational systems used. Especially as both countries are in ASEAN and share similar ethnicities and cultures, comparing the science curricula between the two is very intriguing. In recent years, Indonesia has recognized the critical role of STEM in achieving science learning goals, leading to increased research interest in STEM education, and research on STEM in Indonesia has increased annually (Ilma et al., 2023a). Asian countries also contribute significantly to STEM education research (Ha et al., 2020). Involving 4768 students from 54 studies conducted through systematic reviews and meta-analysis shows that STEM education in Asian countries is effective in improving student learning outcomes, focusing on higher-order thinking skills (Çevik, 2018; Wahono et al., 2020).

Many studies have examined comparisons of science curricula across countries, but few have delved deeper into the comparison of science curricula from the perspective of STEM education at the higher education level. Research by Ow Yeong et al. found that comparisons of science curricula in East Asian countries at the elementary level showed that one comparison among East Asian countries is the development of science literacy focusing on data literacy in science curricula. In Singapore, teaching emphasizing data literacy is still very limited. However, compared to other content domains, data literacy emphasizes higher-order cognitive domains, including the use of mixed data visualization. Compared to East Asian countries, lower-performing Singaporean students in the 10th percentile generally do not outperform students in East Asia. Thus, integrating data literacy skills and competencies into the science curriculum is recommended (Ow-Yeong et al., 2023). ilva et al. found that comparisons of science curricula at the elementary education level in Portugal, the UK, the USA, Australia, and Singapore showed that in Portugal, science education at the elementary level is integrated into the subject "Environmental Studies," which covers physical and natural sciences as well as social sciences, which is not present in the curricular organization of the other analyzed curricula. The results show that the Portuguese curriculum, compared to the others, presents a lower integration of physical and natural science learning, prioritizes knowledge over skills and attitudes and values, and shows fewer explicit guidelines for science teaching (Silva et al., 2023).

Previous comparative curriculum reviews have been conducted in-depth, but these studies focus more on general science curriculum comparisons at the elementary education level and have not extensively explored STEM education comparisons in science curricula, which have become a recent trend. Furthermore, analyzing curriculum development at the higher education level is important because curriculum development at this level is a key indicator of preparing human resources ready to work and compete globally(Munna, 2022;

Rianto et al., 2022). For these reasons, higher education curricula, particularly in science education, need to be reviewed as they require graduates to be individuals capable of critical thinking and generating new ideas that contribute to the advancement of science and technology, including leadership skills, teamwork, and interpersonal skills. This is an important part of holistic development that is less emphasized in previous education levels.

Considering the ever-evolving curriculum, particularly the implementation of STEM in the science curriculum, a systematic literature review can explore researchers' and educators' efforts in developing STEM education. Literature reviews are used to gain a deeper understanding of the topics being researched. Using literature review is an effective method for creating a strong foundation to facilitate knowledge and support theory development(Webster & Watson, 2002). By integrating findings and perspectives from many empirical studies, literature reviews can answer research questions that individual studies cannot (Snyder, 2019). Additionally, literature reviews are the best way to synthesize research findings to create theoretical frameworks and build conceptual models (Snyder, 2019). Analyzing the comparison of science curricula in Singapore and Indonesia can provide insights into Singapore's achievement as the top-ranked ASEAN country globally. Overall, the comparative framework of the curricula in Singapore and Indonesia provides a comprehensive overview for other countries on how STEM education is integrated into the science curriculum.

Based on the above explanation, this study aims to analyze the comparison of STEM education curricula at the higher education level in Singapore and Indonesia, and to promote STEM education curriculum reform at the higher education level in Indonesia. These findings can be recommendations for stakeholders, particularly science educators, in developing science learning and can serve as a strong basis for planning and developing more effective STEM education curricula that encourage and strengthen 21st-century skills, which are crucial in current science learning.

LITERATURE REVIEW

STEM Learning

The definition of STEM education is very broad. According to Bybee (Bybee, 2013), STEM education can be a subject, intradisciplinary, interdisciplinary, or focused discipline. STEM education integrates science, technology, engineering, and mathematics and is defined as interdisciplinary learning (Koul et al., 2018; Thibaut et al., 2018). This is another explanation of STEM education. STEM education emphasizes problem-solving through the integration of various disciplines and other skills, including science, technology, engineering, and mathematics (Wahono et al., 2020). By integrating knowledge and skills in an interdisciplinary way, STEM education aims to equip students (Nguyen et al., 2020). As a result, effective analysis using a variety of viewpoints, abilities, and knowledge is needed for STEM education (Reynante et al., 2020).

Students can acquire a profound comprehension of their environment by means of science. The use of technology will help students develop their skills. Engineering allows students to find solutions to issues. Furthermore, mathematics fosters the growth of students' ability to evaluate data, minimize mistakes, and carefully consider their own solutions (Bardoe et al., 2023). According to Samsudin et al, STEM education is a method of instruction that blends rigorous academic ideas with practical application (Samsudin et al., 2017). Students benefit from STEM education because it gives them the chance to use their creativity to solve problems across a variety of subject areas (Chang & Lee, 2022; Wahono et al., 2020).

Science Curriculum

The curriculum can also play an important role in preparing students for career success through the development of literacy, numeracy, inquiry-based practices, global citizenship values, the use of information technology, creativity, and critical thinking (Frank Angelo, 2023). Rhode Island Departmen of Education (RIDE) defines curriculum as a sequence of standards-based planned experiences in which students practice and achieve proficiency in content and applied learning skills. The curriculum is the primary guideline for all educators regarding what is essential in the teaching and learning process, ensuring that every student has access to rigorous academic experiences (RIDE, 2021). RIDE describes the effective implementation of the curriculum as requiring good cooperation from all stakeholders.

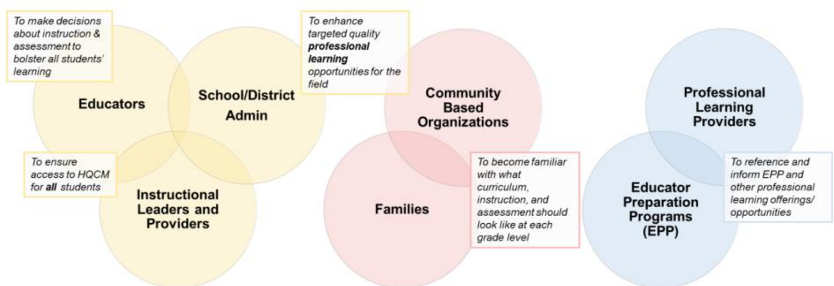

Figure 2. The Effective Implementation of the Curriculum (RIDE, 2021)

For students to fully comprehend scientific concepts and reach their full potential in the twenty-first century, an adaptive science curriculum that keeps up with scientific and technological advancements is imperative (Abdurrahman, 2022). The concept of continuous learning is a modern educational philosophy that seeks to develop curricula and methods that support the development of abilities and mindsets necessary for success in a complex and dynamic environment (Hays & Reinders, 2020).

From elementary school through advanced education, the science curriculum provides the cornerstone for fundamental knowledge. The purpose of this curriculum concept is to assist students in comprehending and honing their scientific knowledge and skills. The science curriculum offers a solid basis for comprehending the fundamental ideas of the natural sciences at the elementary school level (Moon & Blackman, 2014). However, as students advance to the middle school level, the emphasis changes to a more in-depth and sophisticated comprehension of concepts. In order to better prepare students for increased scientific knowledge exploration, the advanced science curriculum incorporates elements of research and scientific application (Lederman et al., 2013).

METHODOLOGY

A systematic literature review was used in this study to identify and critically assess relevant research, gather data, and analyze the results of these studies as an effort to develop theory (Liberati, 2009; Webster & Watson, 2002). This study utilized the Publish or Perish (PoP) software to review literature published between 2020-2024. Cronin et al. mention that ideally, the document range in a systematic literature review is 5-10 years (Cronin et al., 2008), so a 10-year range was chosen for data collection in this study. Data collection used the Google Scholar database. Data selection was conducted using the PRISMA method adapted from Kulakli & Osmanaj; Yang et al.; Bonilla-Chaves & Palos-Sánchez; Wei et al. (Bonilla-Chaves & Palos-Sánchez, 2023; Kulakli & Osmanaj, 2020; Wei et al., 2023; L. Yang et al., 2017). The PRISMA method was used because it provides a methodology that contributes to quality assurance in the review and data replication process using procedures such as determining information sources, the selection process, data collection process, determining eligibility criteria, and selecting data items (Tedja et al., 2024).

The literature search was conducted in April-May 2024 with the first keyword search being "STEM education in curriculum higher education in Singapore and Indonesia," resulting in 9,018 documents. Then, the documents were limited to journal publications, resulting in 732 documents. The relevance of these documents to the research topic was analyzed, resulting in 246 documents. These relevant documents were further identified by reviewing the main focus (STEM learning in higher education in Singapore and Indonesia). From a more detailed identification, 40 article documents were found to be suitable and were designated as data sources for analysis in this study.

RESULTS

Objectives of STEM Learning Curriculum at the University Level in Singapore and Indonesia

The trending and implemented education curriculum in Singapore is the STEM education curriculum. The STEM program in Singapore has been ongoing since 2004. This program aims to provide learning opportunities about real life through hands-on practical activities. Some previous literature provides research results on the objectives of the STEM education curriculum at the university level in Singapore. The summary of the results is presented in table 1.

Table 1. Review of the Objectives of the STEM Learning Curriculum at the University Level in Singapore

Article Title	Journal Name	Research Results
A Comparative Study of Integrated STEM Curriculum in Finland, Singapore and the United States to Provide Recommendations for Iranian Curriculum Planners (M. Rezaei et al., 2022)	Iranian Journal of Comparative Education	The purpose of STEM is to train individuals in mastering basic sciences so that they can make rational decisions based on scientific facts.
STEM Education Landscape: The Case of Singapore (Teo, 2019)	*Journal of Physics: Conference Series*	The aim of STEM is for students to gain strength in learning related to their future careers.
Change theory in STEM higher education: a systematic review (Reinholz et al., 2021)	International Journal of STEM Education	STEM aims to improve the quality of individuals and build general knowledge about future changes.
Using Technology to Support Student Learning in an Integrated STEM Learning Environment (D. Yang & Baldwin, 2020)	International Journal of Technology in Education and Science	STEM education is present as a means to enhance the quality of students who are innovative and creative in facing future interdisciplinary challenges.
STEM-E: Fostering mathematical creative thinking ability in the 21st Century (Suherman et al., 2021)	Journal of Physics: Conference Series	STEM is recognized for providing students with more comprehensive learning and experiences.

Article Title	Journal Name	Research Results
STEM Education Discrepancy in the United States and Singapore (Clevenger et al., 2016)	Beyond: Undergraduate Research Journal	STEM is intended to help students understand university materials and be ready to face challenges as technology advances in the world.
Bridging the Gap between Secondary and Higher STEM Education – The Case of STEM @ school (De Meester et al., 2020)	European Review	STEM in higher education is important for providing a competent workforce.
Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education (Shernoff et al., 2017)	International Journal of STEM Education	STEM emphasizes the interdisciplinary relationships between concepts and skills to ensure knowledge of each discipline and to connect these concepts and skills to authentic problems.
Journey of science teacher education in Singapore: past, present and future (A. Tan, 2018)	Asia-Pacific Science Education	STEM emphasizes the interdisciplinary relationships between concepts and skills to ensure knowledge of each discipline and to connect these concepts and skills to authentic problems.
At the dawn of science, technology, engineering, arts, and mathematics (STEAM) education: prospects, priorities, processes, and problems (Belbase et al., 2022)	International Journal of Mathematical Education in Science and Technology	STEAM becomes a new vision to encourage creativity, collaboration, and togetherness among students through transdisciplinary awareness and conscience.
From STEM to STEAM: Strategies for enhancing engineering and technology education (Connor et al., 2015)	International Journal for Engineering Pedagogy	STEAM functions to create teaching theories and practices that span various disciplines.

Based on table 1, it can be concluded that the goal of STEM learning at the university level in Singapore is to enhance the quality of individuals so that they are prepared to face the challenges of future developments related to multidisciplinary knowledge and 21st-century skills. The output of STEM learning at universities is expected to produce a generation that is competent and globally competitive, in line with 21st-century skills.

Not only has Singapore implemented STEM in learning, but Indonesia has also become one of the countries that apply STEM in its education system. Several previous studies have discussed STEM learning at the university level. The summary of these studies is presented in table 2.

Table 2. Review of the Goals of the STEM Learning Curriculum at the University Level in Indonesia

Article Title	Journal Name	Goals
STEM learning environment: Perceptions and implementation skills in prospective science teachers (Rusydiyah et al., 2021)	Jurnal Pendidikan IPA Indonesia	STEM aims to train students in combining four different disciplines and solving problems related to participants' real-life experiences.
STEM Education in Indonesia: Science Teachers' and Students' Perspectives (Permanasari et al., 2021)	Journal of Innovation in Educational and Cultural Research	STEM learning can be used to focus on understanding the integrated nature of science, technology, engineering, and mathematics disciplines, as well as their importance in the long-term academic success of children and economic well-being.
Literature review: a STEM approach to improving the quality of science learning in Indonesia (Nurwahyunani, 2021)	Journal for the Education of Gifted Young	STEM aims for participants to enhance their focus on everyday problems.
The development of electrolysis cell teaching material based on STEM-PJBL approach assisted by learning video: A need analysis (Widarti et al., 2020)	Jurnal Pendidikan IPA Indonesia	STEM aims for participants to enhance their focus on everyday problems.

Article Title	Journal Name	Goals
Mathematics Learning Process with Science, Technology, Engineering, Mathematics (STEM) Approach in Indonesia (Milaturrahmah et al., 2017)	IOP Conf. Series: Journal of Physics: Conf. Series	STEM can train abilities and talents in facing 21st-century problems.
The Types of STEM Education Implementation in Indonesia (Diana et al., 2017)	Journal of Xi'an University of Architecture & Technology	The application of STEM is aimed at enabling participants to develop interests, attitudes, and skills needed in the 21st century, including communication that refers to argumentation skills.
A Systematic Literature Review of STEM Education in Indonesia (2016-2021): Contribution to Improving Skills in 21 st Century Learning (Ilma et al., 2023b)	Pegem Journal of Education and Instruction	The application of STEM is aimed at enabling participants to develop interests, attitudes, and skills needed in the 21st century, including communication that refers to argumentation skills.
STEM research trends in Indonesia: A systematic literature review (Ardwiyanti et al., 2021)	Journal of Science Education Research	STEM learning intends to enhance various soft skills needed in the workforce, especially in STEM fields, such as high-level thinking, problem-solving, critical and creative thinking, reasoning, collaboration, and decision-making.

Based on table 2, it is concluded that the goal of STEM learning at the university level in Indonesia is to shape and enhance students' soft skills needed in the workforce, especially in STEM-related fields, and in line with the demands of 21st-century skills.

STEM Learning Curriculum Aspects at the University Level in Singapore and Indonesia

The Singapore Science Center has been collaborating with the Ministry of Education since 2013 to implement a holistic STEM department. The goal of this program is to address new challenges in the global market. The STEM learning curriculum at the university level is aimed at being implemented to its fullest potential. This implementation is inseparable from components that support STEM education at every level of education. According to Oner & Capraro STEM learning can succeed if it meets four aspects as depicted in figure 2 (Öner & Capraro, 2016).

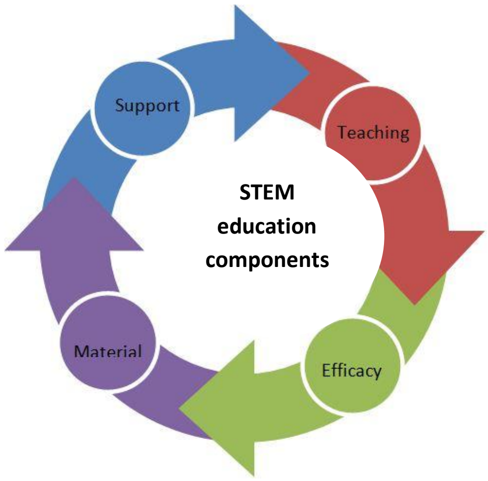

Figure 3. Components Supporting STEM Education

As depicted in Figure 3, the aspects of STEM education consist of support, teaching, efficacy, and material aspects. The support aspect relates to collaborative support for implementing STEM education. The teaching aspect concerns mastery of learning, including preparation and implementation in the classroom. The efficacy aspect relates to confidence in STEM education, starting from mastering the material and commitment to learning. The material aspect pertains to facilities and infrastructure supporting learning. These aspects are also implemented in universities in Singapore. Below is a summary of the aspects of STEM education implemented in higher education institutions.

Table 3. Aspects of STEM Education in Universities in Singapore

STEM Education Aspect	Description
Support	STEM education in Singapore is supported by the Government, Industry, and Educational Institutions. The support provided includes the implementation of STEM integrated with classroom learning. Universities in Singapore facilitate students to participate in training or internships in both public and private institutions related to STEM. For example, collaborations between National Institute of Education (NIE) and Teacher Education Institutes (LPTK), as well as science exhibitions and handicraft activities held in Singapore shopping centers sponsored by the Science Centre Singapore (Clevenger et al., 2016).
Teaching	Teaching Educators' mastery of teaching to apply STEM approaches is well-established, demonstrated by their ability to design, implement, and review STEM curricula. Educators integrate STEM approaches with other teaching models or media to maximize the learning process. For example: smart learning (Benita et al., 2021), hands-on experience (Wang & Hooi, 2019), inquiry and technology (Vicente et al., 2024), problem-solving (Chen et al., 2019), among others.
Efficacy	Faculty members and students at universities in Singapore have confidence in implementing STEM education. Faculty members believe that STEM education can influence students' skills and competitiveness in accordance with global demands (Or et al., 2022).
Material	All educational needs required by students are complete and of the highest quality, such as libraries, classrooms, sports facilities, interaction spaces, cafeterias, and others (Teo & Choy, 2021).

Table 3 informs that STEM education in Singapore has fulfilled four aspects: support, teaching, efficacy, and material. The support aspect is marked by the government and non-governmental institutions' support in collaboration with universities in Singapore, both in the form of internships and exhibitions. The teaching aspect is characterized by educators' ability to implement STEM through integrating STEM approaches with other teaching models, such as problem-solving, smart learning, technology, and so on. The efficacy aspect is marked by educators' readiness to implement STEM, leading companies or government agencies to trust and fully support STEM needs in schools or universities. The material aspect is marked by the availability of facilities and infrastructure needed by educators in universities to carry out STEM, such as complete campus facilities.

STEM education in Indonesia has also fulfilled aspects similar to those in Singapore. The implementation of STEM is inseparable from the collaboration carried out by every university with STEM partners in Indonesia. This partnership is established with industry, government, society, and international research institutions. Strategic partnerships are developed between educational institutions (such as universities) and STEM-related companies and industries. This is manifested in the form of internships, industrial visits, and collaborative projects. This scheme aims to integrate practical experience into the curriculum and ensure the relevance of students' skills to industry needs. Collaboration is also conducted with government and civil society, including non-profit organizations, local communities, and parents. Partnerships with international research institutions are also conducted to support knowledge exchange, joint research, and global-scale STEM education programs. This scheme provides broader access to international resources and experiences, enriching the learning and research environment domestically.

In Indonesia, the implementation of STEM also considers four important aspects. A more detailed elaboration of the implemented STEM learning aspects at the university level in Indonesia is recorded in Table 4.

Table 4. STEM Learning Aspects in Indonesian Universities

STEM Learning Aspect	Description
Support	The support for STEM learning in Indonesia is fulfilled by various governmental and private institutions, industries, communities, and international research institutions. During the implementation of the independent learning curriculum, the government fully supports the collaboration between universities and external parties (Diana et al., 2017). Many universities or institutes collaborate with other institutions outside academia. For example, internship programs, industrial visits, and collaborative projects conducted by students are carried out in government agencies implementing STEM, such as the Center for Development and Empowerment of Educators and Education Personnel (P4TK) IPA Bandung. Also, collaborations with private institutions, such as Mitsubishi focusing on engineering and machinery, PT PLN, manufacturing companies, and others.
Teaching	Many universities or institutes collaborate with other institutions outside academia. For example, internship programs, industrial visits, and collaborative projects conducted by students are carried out in government agencies implementing STEM, such as the Center for Development and Empowerment of Educators and Education Personnel (P4TK) IPA Bandung. Also, collaborations with private institutions, such as

STEM Learning Aspect	Description
	Mitsubishi focusing on engineering and machinery, PT PLN, manufacturing companies, and others. (Rahmania, 2018), STEM Project-Based Learning and Discovery Learning (Purwaningsih et al., 2020), combinations with student learning modules (Pathoni et al., 2021), and others.
Efficacy	So far, educators understand STEM with three keywords: collaboration, product generation, and problem-solving. Some educators do not emphasize specific courses, which can be interpreted as STEM cannot be applied to subjects other than science and mathematics. According to educators, the curriculum of study programs must be designed with a STEM learning environment approach to have good teaching capabilities. They realize that STEM learning is an effective approach to enhance Higher Order Thinking Skills (HOTS). Educators' sources of knowledge include the internet, lecture materials, STEM leadership symposiums, international seminars, STEM training, and peer colleagues (Diana et al., 2017; Nugroho et al., 2021)
Material	Facilities and infrastructure for STEM learning are available at several universities in Indonesia. For example, there are science laboratories, machining laboratories, mathematics laboratories, and other facilities (Firman, 2016).

Based on Table 4, it can be concluded that STEM learning at the university level in Indonesia fulfills four aspects: (1) support characterized by collaboration between universities and external parties, both governmental and non-governmental; (2) teaching marked by the integration of STEM learning with various other learning models/media; (3) a significant number of educators have mastered STEM learning independently or collectively; and (4) the availability of facilities and infrastructure supporting STEM learning at the university level.

Implementation of STEM Learning Curriculum at the University Level between Singapore and Indonesia

Based on journal analysis results, data show that STEM education in Singapore demands teachers to develop expertise in various subject areas, especially science and mathematics. Educators at universities in Singapore are required to apply STEM approaches to design, implement, and review STEM curricula. Learning with a STEM approach in Singapore can enhance the quality of educators (lecturers), such as providing a good understanding of required competencies and enhancing productive thinking patterns as a lecturer (Teo & Choy, 2021). The impact of the STEM approach at the university level helps improve education in Singapore.

Learning with a STEM approach is done integratively by directly addressing real-life problems and seeking better solutions. STEM knowledge in Singapore covers various fields, especially science and technology, followed by mathematical formulas, physics formulas, and many others in the field of knowledge (Kelley & Knowles, 2016). Therefore, the development of STEM in Singapore can be considered very good and highly needed among students. STEM education has gained attraction in Singapore and worldwide for various sciences and skills with a discipline style to meet the demands of the STEM revolution in Singapore. Previous research discussed the meriSTEM@NIE integration process in STEM. Figure 3 presents the STEM learning framework starting with problems with three characteristics (persistence, complexity, and expansion) (Teo & Choy, 2021).

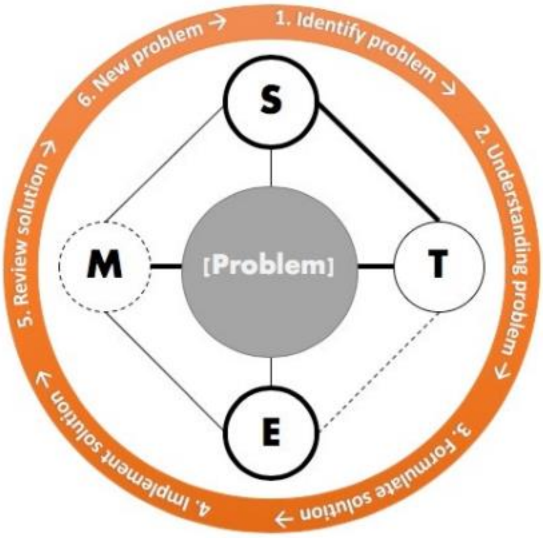

Figure 4. STEM Quartet Learning Framework Developed by MeriSTEM@NIE

Based on Figure 4, the first step is to identify the problem. In this case, the STEM problem refers to issues that prompt learners to think about schemes and solutions. Next, students are required to understand the existing problems, especially those found in their environment. They then brainstorm solutions according to the needs of the surrounding conditions. Students design and build prototypes and test the effectiveness of the solutions they have devised. The results of these designs are then implemented practically in lectures or daily life. The implementation data of these STEM problem solutions is reviewed or reflected upon with feedback or suggestions.

Nanyang Polytechnic (NYPi) in Singapore is also a location where STEM learning is implemented. NYPi has the concept of a teaching factory as one of the supports for STEM learning. This concept includes integrating industry culture, project activities, building business collaborations, and serving as a provider of expertise and technological resources. NYPi conducts similar learning assessments to Indonesia, namely formative and summative assessments. NYPi also serves as a center for AM(3DP), MakerSpaceNYP, and Flipped learning, which are highly beneficial for STEM learning. The curriculum implemented at NYPi consists of internal curriculum (communication, modules, and projects) and external curriculum (extracurricular activities).

With the various advantages provided by NYPi in STEM learning, it is not surprising that NYPi graduates possess professional skills that are in line with 21st-century skills. They have skills that meet the needs of the global era, are innovative and entrepreneurial, creative, capable of innovatively and practically creating something different in the entrepreneurial world, and are service-oriented and responsive to the environment and society.

STEM education in Indonesia also encompasses four subjects: science, technology, engineering, and mathematics. According to the Big Indonesian Dictionary, these four fields of study have different meanings, namely: (1) science, systematic knowledge obtained from observation, research, and experimentation leading to the principles of something being investigated and studied; (2) technology, the whole means to provide goods necessary for human survival and comfort; (3) engineering, the approach or STEM to work on something; and (4) mathematics, the science of numbers, the relationship between numbers, and operational procedures used in solving problems related to numbers.

Several courses in Indonesian higher education still intersect with STEM. Previous findings mentioned that courses in the Elementary School Teacher Education Program intersect with STEM, such as basic science concept courses, advanced science concept courses, number mathematics, geometry mathematics, probability data mathematics, elementary science learning courses, elementary mathematics learning courses, ICT courses, applied statistics courses, instructional media development courses, microteaching courses, and elementary school learning innovation courses. The combination of STEM disciplines has been applied in one course. For example, in the basic science concept and electrical concept courses.

Through lectures with the STEM approach, students become more aware that these four subjects cannot be separated, and they must collaborate and solve problems. Sulaeman et al. (May & Cheng, 2022) identified several strategies adopted by Indonesian universities in redesigning their programs to meet STEM preparation needs, including designing new mandatory STEM education courses, integrating STEM into other pedagogical courses, and providing elective courses and extracurricular activities.

The process of STEM education in learning and courses at higher education institutions is implemented by considering several stages. These stages consist of: (a) asking questions (science) and defining problems (engineering); (b) developing and using models; (c) planning and conducting investigations; (d) analyzing and interpreting data (mathematics); (e) using mathematics, information technology, and computers, as well as computational thinking; (f) constructing explanations (science) and designing solutions (engineering); (g) engaging in argumentation based on evidence; and (h) obtaining, evaluating, and communicating information (National Research Council, 2012). There are also opinions about five stages of STEM learning, which are asking, imagining, planning, creating, and improving (Arlinwibowo et al., 2021). Meanwhile, findings from other experts suggest that the stages of the STEM approach can be applied with the syntax: orientation (reading learning resources), exploration (asking questions), reasoning (elaborating concepts in a particular content by arguing), creating (applying concepts to solve problems), and communicating (reporting performance results) (Nasir et al., 2022; Sutoyo et al., 2019).

Building on the description of STEM education implementation in Singapore and Indonesia, the results of the comparison of STEM education implementation are summarized. The summary of results is presented in Table 5.

Table 5. Comparison of STEM Education Implementation

No	Aspect	Indonesia	Singapore
1	Quality of Educators	Educators are a factor that influences students' outcomes and achievements	Educators collaborate in implementing STEM by designing, implementing, and reviewing the STEM curriculum
2	Quality of Students	Students can independently solve problems according to the issues and solutions they encounter	Students can develop and use technology, and apply their knowledge
3	Improvement of STEM Implementation Quality	STEM has the potential to facilitate students in discovering new ideas (related to STEM) and actively involve them during the course process	STEM education in Singapore is directed towards knowledge and skills with disciplinary knowledge to meet the demands of the STEM revolution in Singapore
4	Materials	Most courses can be integrated with STEM learning	Most courses can be integrated with STEM learning, but predominantly in science and mathematics courses
5	STEM Learning Framework	a. Orientation b. Exploration c. Reasoning d. Creation e. Communication	a. Problem b. Identification c. Problem d. Understanding e. Solution f. Formulation g. Solution h. Implementation i. Solution review j. New problems

Comparison of STEM Education Curricula at the Higher Education Level between Singapore and Indonesia

STEM education is part of the Sustainable Development Goals (SDGs) program. Every country in Asia and beyond has endeavored to implement STEM in schools and higher education institutions. Singapore, as one of the developed countries in Asia, has implemented STEM education since the primary education level. STEM education in Singapore has been ongoing since 2004 and continues to this day. Besides Singapore, Indonesia is also a country implementing STEM, applied at the primary education level. STEM education in both Singapore and Indonesia focuses on science, technology, engineering, and mathematics. STEM education is reviewed from several important aspects, such as objectives, aspects, and implementation. The description of (objectives, aspects, and implementation) shows differences in how it has been carried out in Singapore and Indonesia. The differences in STEM education are reviewed from several aspects. A summary of the differences is presented in Table 6.

Table 6. Comparison of STEM Education at the Higher Education Level in Singapore and Indonesia

No	Component	Singapore	Indonesia
1	Objectives	Improve the quality of individuals who are ready to face future challenges related to multidisciplinary knowledge and 21st-century skills	Enhance students' soft skills needed in the workforce, especially related to STEM and 21st-century skills
2	Aspects	a. Support b. Teaching c. Efficacy d. Material	a. Support b. Teaching c. Efficacy d. Material
3	Implementation	The implementation of STEM education has been optimally conducted for both educators and students, although only a few subjects (science and mathematics) can be integrated with STEM through the learning framework: problem identification, problem understanding, solution formulation, solution implementation, solution review, and new problems	The implementation of STEM education is maximally carried out by educators and students, along with the integration of STEM with existing courses through the learning framework: orientation, exploration, reasoning, creation, and communication

DISCUSSION

Singapore is a country that falls into the category of developed countries in Asia. Many aspects drive Singapore to become a developed country, such as economic, political, and educational aspects. Singapore's education system has long been renowned and internationally recognized for its high quality. It is not surprising that many people strive to pursue higher education in Singapore. The Singaporean government continually pays attention to the development and refinement of its educational curriculum. This is done to ensure that the next generation receives quality education that is relevant to the times. The education curriculum in Singapore is known for its quality of knowledge. There are four levels of education structure in Singapore: primary school, secondary school (lower and upper), post-secondary school or pre-university (equivalent to diploma level), and university (undergraduate level). The goal of STEM learning at the university level in Singapore is to enhance the quality of individuals so that they are prepared to face the challenges of future developments related to multidisciplinary knowledge and 21st-century skills. The output of STEM learning at universities is expected to produce a generation that is competent and globally competitive, in line with 21st-century skills (Reinholz et al., 2021; M. Rezaei et al., 2022; Teo, 2019).

. STEM in Indonesia is recognized as a national movement committed to advancing literacy and education in the fields of Science, Technology, Engineering, and Mathematics (STEM). STEM Indonesia acts as a driving force to produce an excellent generation that is ready to face future challenges. STEM learning at the university level in Indonesia fulfills four aspects: (1) support characterized by collaboration between universities and external parties, both governmental and non-governmental; (2) teaching marked by the integration of STEM learning with various other learning models/media; (3) a significant number of educators have mastered STEM learning independently or collectively; and (4) the availability of facilities and infrastructure supporting STEM learning at the university level. STEM education focuses more on problem analysis and supports 21st-century skills (Milaturrahmah et al., 2017; Permanasari et al., 2021; Rusydiyah et al., 2021).

In the context of the national curriculum, STEM education in formal schools in Singapore is embedded in Mathematics Education and Science Education. Besides discipline-based integration, STEM education programs across states, mostly in the form of extracurricular activities, are provided by the Agency for Science under the supervision of the Ministry of Education to promote STEM education in Singapore. The Ministry of Education in Singapore employs an environment-based approach towards implementing STEM education at the university level involving curriculum design elements, pedagogical practices, and professional development (Fern et al., 2020).

Overall, the implementation of STEM in Singapore can encourage students to develop and use technology, hone their knowledge, and apply it in practice (Kapila & Iskandar, 2014). Therefore, the STEM approach is highly significant in the lecturing process. Lecturing with a STEM approach can train students to create designs for technology-based problem-solving. STEM focuses on teaching science issues to students at each educational level, highlighting their real-world applications. STEM learning aims to foster student creativity and help them think comprehensively (Ritz & Fan, 2015). The STEM education process is carried out directly through experimentation.

CONCLUSIONS AND RECOMMENDATIONS

The comparison of STEM education curricula in Singapore and Indonesia can be seen from three perspectives: objectives, aspects, and implementation. Both Singapore and Indonesia have objectives aimed at the formation and enhancement of individual skills as preparation for facing challenges and meeting the needs of the workforce, particularly in 21st-century skills. STEM education in both Singapore and Indonesia includes similar aspects in terms of support (supported by government and non-government institutions), teaching (integration of teaching with other models/techniques), efficacy (educators' confidence in their ability to implement STEM), and material (availability of facilities that support learning). The implementation of STEM education in Singapore and Indonesia has been optimal for both educators and students, accompanied by the integration of courses with STEM through a learning framework. The recommendation from this study is that the STEM learning process in higher education needs to be synergized with other study programs so that students can gain a closer understanding of the basic concepts of the five fields of study in STEM. For future researchers, it is suggested to analyze more deeply the technical implementation of STEM education in classrooms from several countries focusing on one similar study program.

On the other hand, from several research findings in Indonesia, the quality of teachers becomes a crucial factor that can influence students' achievements, not exempted in higher education. This serves as a reminder that the quality of teachers in terms of knowledge significantly correlates with the instructional quality of learning achievements (Kersting et al., 2012). Thus, the quality of teachers implementing the STEM approach is one effort to enhance the quality of education.

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