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STEAM in the Perspective of 21st Century Mathematics Learning: A Field Study of Indonesia and Malaysia

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ABSTRACT

The aim of this study is to explore the implementation of the STEAM approach in Indonesia and Malaysia in relation to mathematics learning concepts and the skills developed during the mathematics learning process. This study employs a descriptive qualitative method with school students as the research subjects, aiming to examine the application of STEAM in the learning process in both countries. The findings reveal that the integration of STEAM has a positive impact on mathematics learning, particularly in enhancing students' confidence as well as their critical thinking, creativity, communication, and collaboration skills. The application of STEAM in the context of 21st-century mathematics education encourages students to build self-confidence in facing challenges, which is essential for maximizing their potential.

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INTRODUCTION

The implementation of the STEAM approach in learning can increase positive impacts related to student learning outcomes (Pahmi et al., 2022). Several research findings support this statement (Pratiwi & Khotimah, 2022; Amanova et al., 2025; Supianti et al., 2025). The characteristics of the STEAM approach, which directs students as educational subjects, make students have a high sense of self-confidence and responsibility in the learning process. One of the main factors that determine student success is their confidence in their abilities when solving problems.

STEAM is not only applied in learning in one region or country, but also in several countries because STEAM has a positive impact on the learning process (Duma, 2024). STEAM can improve students' 21st-century skills (Safitri, 2022). 21st-century skills that students need to master include critical thinking skills, creative thinking skills, communication skills, and collaboration skills. Among these 21st-century skills, critical thinking skills play a crucial role in the learning process (Collins & Eastabrook, 2023). One of the important roles of having critical thinking skills is to optimize the problem-based learning process (Wardani & Fiorintina, 2023). Critical thinking skills can be

encouraged with the STEAM approach (Iljannah et al., 2025). The indicators in STEAM can help students with investigating, assembling, and interpreting. Through these verbs, it is hoped that students can improve their critical thinking skills. When students investigate, assemble, and interpret, there is a process of higher-order thinking skills being carried out. Critical thinking skills are an aspect that students need to master in solving 21st-century problems (Ellianawati et al., 2025). In addition to critical thinking skills, something that needs to be strengthened is creative thinking skills. Creative thinking skills are skills that need to be mastered well by students facing 21st-century learning (Kismawardani et al., 2022; Ishartono et al., 2024). Through 21st-century skills, students have the ability to find several alternative solutions in the problem-solving process (Rosikhoh et al., 2019).

Critical thinking skills and creative thinking skills need to be supported by good communication skills (Sope & Murtono, 2024) (Dias-Oliveira et al., 2024). Good communication skills can convey existing messages so that they can be understood by others (Zuhri & Sya'adiyah, 2023). Good ideas or concepts require a good delivery process. This is important to convey correct information in full. Inappropriate communication delivery can result in misinterpretation so that the intended message cannot be followed up properly.

Collaborative skills enhance critical thinking, creative thinking, and communication skills (Suyato et al., 2024). These four skills need to be mastered by students, which can be enhanced through the application of the STEAM approach in learning to prepare students for 21st-century learning (Adiansyah et al., 2024). Strengthening the implementation of STEAM is needed to strengthen students' abilities in facing global challenges (Zaqiah et al., 2024).

Mapping the implementation of modern STEAM does not only capture one region or one country. It is necessary to describe the implementation of STEAM in a region involving several countries. The region taken in this study is a portrait of the countries of the Southeast Asian region. Therefore, this study needs to identify the implementation of the STEAM approach in Indonesia and Malaysia in 21st-century learning. Indonesia and Malaysia are used as representatives of the implementation of STEAM countries in the Southeast Asian region, which is a regional area and has almost the same characteristics related to culture and language. There has been no previous research on STEAM involving several countries in a region that have cultural and linguistic similarities. This research is important to adapt good practices related to the implementation of the STEAM approach from various countries.

METHOD

The research method used was descriptive qualitative with a comparative case study, where the researcher served as the key instrument. Data collection involved field observations. In this study, the researchers observed the implementation of the STEAM approach by Indonesian junior high school teachers in Semarang City and Malaysian teachers in Seremban City, Negeri Sembilan District, Malaysia.

The observations were conducted over three days at a school in Seremban, Malaysia, and three days at a school in Semarang, Indonesia. Data collection included observing the implementation of the STEAM approach in junior high schools. Data collected included student products and teacher explanations of how the STEAM approach was implemented in learning.

This observation activity was supported by semi-structured interviews to dig deeper into the information needed in the process of implementing the STEAM approach carried out in schools in Indonesia and Malaysia. The form of information is the integration of STEAM in the learning process and the resulting products. These products are a representation of the learning process using the STEAM method. To obtain clear information, researchers conducted interviews with teachers and students to clarify things that were still unclear and obtain complete data to support the research data. Questions asked during the interviews related to what problems were encountered that led to the creation of STEAM products, how the product creation process was carried out, and what the benefits of the developed products were.

In addition to observations and interviews, photographs of products resulting from the implementation of the STEAM approach in the learning process were collected. This documentation can be used to support the data collected through the observation and interviews. This documentation is necessary to connect the observation and interview data to form a complete and accountable set of data for the delivery of supporting information for the research.

Observations, interviews, and supporting documentation for descriptive qualitative research were conducted proportionally to ensure the data obtained could be used to generate valid research information. The instruments used in the data collection process were the same as those used in Indonesian and Malaysian schools.

RESULTS AND DISCUSSION

This study describes the implementation of the STEAM approach and the resulting products in the learning process conducted in Indonesian and Malaysian schools, each observed over a three-day period. Learning with the STEAM approach was conducted in one school in Semarang City, Indonesia, which explained its relationship with

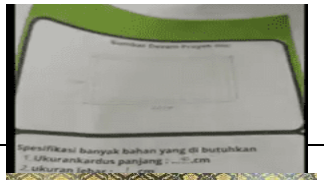
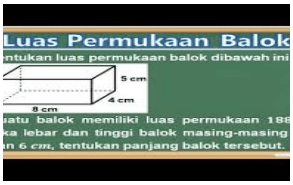
mathematics learning. The problem underlying the implementation of the STEAM approach was related to student uniforms, which when ironed required a fairly high cost in terms of electricity usage.

To address this issue, the teacher instructed students to create an energy-efficient device that could be used to straighten school uniforms. The device can be used as an ironing board to straighten students' clothes. The materials used to create this device included used cardboard, bed sheets, aluminum foil, sewing tools, scissors, a solution, a ruler, a marker, an iron, wrinkled clothes, a thermometer, and a timer. These devices were then modified to create an energy-efficient and environmentally friendly iron, and the device can be modified to be more adaptable and efficient.

The series of tools used to help straighten students' uniforms is adapted to the context of STEAM implementation in the learning process. The Science or knowledge aspect relates to students' understanding of objects that can conduct heat or electrical energy well. The Technology aspect relates to the use of smartphones to find information that can be used as supporting data in creating tools that can be used to produce heat energy well. The Engineering aspect relates to the process of making tools using provided materials and can be used as an environmentally friendly and energy-efficient ironing board. In the engineering process, students are able to produce tools that are the result of the learning process using STEAM implementation. The Art aspect relates to modifying tools that have been made to bring out artistic or cultural aspects. Through this Art aspect, students use batik motifs as covers or ironing boards that can conduct heat energy quickly. Meanwhile, the Mathematics aspect relates to measuring the surface area of the ironing board that is adjusted to the size of the student's clothes or uniform. In the Mathematics aspect, the activities carried out include measuring the surface area of the ironing board and measuring the time required in the process of ironing clothes or school uniforms. Through these activities, students are expected to gain a better understanding of geometric concepts, particularly calculating surface area, and to practice precision in measuring time. The STEAM approach used in these learning activities can be seen in Table 1.

Table 1. Implementation of the STEAM approach in the learning process

Science	Knowledge of heat-conducting materials	
Technology	Use of smartphones or digital media that can be used to	

	search for information about conductor materials	
Engineering	The process of designing, measuring, cutting, sewing and making an energy-saving ironing board	
Art	Design an attractive ironing board using relevant media	
Mathematics	Measuring the surface area of the iron and measuring the time required in the process of ironing clothes or school uniforms	

The explanation above relates to the implementation of STEAM in a junior high school in Semarang (Indonesia), which was motivated by rising electricity costs and the need to create an ironing board that can conduct electricity well, thus shortening the ironing process and saving electricity costs. This product was created through learning that used the STEAM approach.

Next is learning that uses the STEAM approach to produce products that can be used to solve everyday problems. The schools observed in the learning process with the implementation of the STEAM approach are located in Seremban City, Negeri Sembilan District. Researchers conducted direct observations, interviews, and documentation at schools implementing the STEAM implementation. Several products produced in junior high schools or equivalent using the STEAM approach include a dryer and dirt cleaner for feet; a miniature robot; and an environmentally friendly aquarium. These products can be seen in Table 2.

Table 2. STEAM Implementation Products of Negeri Sembilan, Malaysia

Products	Identity	Benefit
	Tool for drying and cleaning dirt on the feet	This tool is used to reduce unpleasant foot odor and can be used to dry wet feet.
	Organic aquarium	This tool is used as a place to keep fish and can also be used as a livestock feeder.
	Robotic Miniatures	This tool is a miniature robot that can be used for various purposes in everyday life in the work process.

Several products produced by students in Seremban, Malaysia, demonstrate how the implementation of STEAM in the learning process can be used to solve problems in everyday life. Students were shown several problems, including how dirty feet can be cleaned with a fairly effective and cost-effective tool. This included the creation of a fish tank that can be used for environmentally friendly fish farming. Furthermore, there were miniature robots that could be developed to assist humans in future work, for example as a driverless, autonomous means of transportation.

Based on the products produced through the implementation of STEAM in the learning process, it shows that these products can be used to solve everyday problems. This demonstrates the benefits of STEAM implementation in strengthening creative and innovative thinking skills. Teachers direct students to identify problems around them and then provide solutions or alternatives that can address these problems. This effort is carried out and can be used to strengthen students' awareness in identifying problems around them and have a high sensitivity to the problems that occur and strive to provide the best solutions to address them.

Products produced to address these problems and that work well can increase student self-confidence. Self-confidence is crucial for students to develop their 21st-century skills (Jeong & González-Gómez, 2024). Self-confidence is crucial for students because they are not afraid to fail or make mistakes when trying new things. The characteristics of the STEAM approach in the learning process are that it directs students to dare to do things they have never done before to construct knowledge (Rosikhoh et al., 2019).

The knowledge construction process can help students learn independently by applying new knowledge they have never learned before, thereby gaining meaningful knowledge in the classroom. This activity supports a student-centered learning process as the subject of education (Tang et al., 2025). Learning with a STEAM approach can help students find meaning in each subject they understand (Muzakkir et al., 2024).

The implementation of the STEAM approach in 21st-century learning is a crucial aspect in improving the quality of regional education (Laksmiwati et al., 2024). Data obtained from field studies in Indonesia and Malaysia indicate a high level of enthusiasm for each learning project undertaken by students. Students gain confidence and a passion for making learning more enjoyable. This can shift the paradigm of mathematics learning from seemingly difficult to enjoyable mathematics learning (Kismawardani et al., 2022). The difference in the implementation of the STEAM approach in mathematics learning in Indonesia and Malaysia is related to the resulting STEAM products. STEAM products produced by students in Indonesia are more oriented towards solving everyday problems, while in Malaysia, STEAM products tend to be used for independent entrepreneurship. In principle, the implementation of STEAM in these two related countries has received a positive response from students and is directly proportional to student learning outcomes. Students have good achievement scores in mathematics learning with the implementation of STEAM.

CONCLUSION

The application of the STEAM approach, particularly in mathematics learning, is a good solution to address the dynamics and developments of 21st-century learning. Educational developments are increasingly complex, and the implementation of STEAM in learning is a good form of adaptation to face the development of the educational world. The 21st-century skills that students need to have include critical thinking and creativity, good communication skills, and efforts to build solid cooperation that can be brought out by the application of the STEAM approach in mathematics learning. There are many advantages that STEAM learning can have in a country. Further research can emphasize the aspect of STEAM Collaboration that can improve the quality of education in a region or the global arena.

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