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The Effectiveness of Mathematics Learning with the STEAM Approach in Improving Students' Critical Thinking Skills

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ABSTRACT

This study aims to assess the effectiveness of the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach in mathematics learning to improve students' critical thinking skills through a literature review method. The STEAM approach integrates various disciplines with the aim of creating relevant and innovative learning experiences, so as to support the development of critical thinking skills. This study utilizes a literature review method, where various sources such as scientific journal articles, academic books, and related publications are analyzed to identify the impact of the STEAM approach on improving students' critical thinking skills in mathematics learning. The analysis was carried out descriptively qualitatively by reviewing the results of previous studies that discussed the implementation of STEAM. Based on this study, it was found that the application of STEAM in mathematics learning consistently had a positive impact on improving students' critical thinking skills. This is due to the nature of the STEAM approach which encourages collaboration, analytical thinking, and the application of theoretical concepts to practical contexts. This study shows that the STEAM approach is effective in developing high-level thinking skills and can be used as an innovative learning model at various levels of education.

INTRODUCTION

In the context of modern education, technological developments and globalization have changed the landscape of graduate competency needs. The world of work and society in general require a young generation who not only have adequate academic knowledge, but also critical thinking skills that can be applied in complex real situations (Ronnlund et al., 2019). This is becoming increasingly important amidst the rapid development of technology, where information can be accessed quickly, but must be evaluated carefully and wisely. Students are no longer just passive recipients of information, but are also expected to be able to process, analyze, and apply the knowledge gained effectively. Critical thinking skills include various skills, such as the ability to identify problems, collect and evaluate relevant data, make logical inferences, and evaluate solutions based on available evidence. In an increasingly complex world,

these skills are in great demand, especially in fields that require systematic problem solving, such as mathematics. Mathematics not only requires mastery of concepts and procedures, but also requires students to think logically and critically in solving the problems faced.

Modern education requires innovation in the learning process in order to maximize students' potential as a whole (Vockley, 2020). One of the crucial skills that need to be developed is critical thinking skills, which are the foundation for students to face future challenges. These skills enable students to solve problems, make informed decisions, and evaluate information logically and in-depth. In the context of mathematics learning, critical thinking skills are very important, because a good understanding of concepts and analysis is the key to success. Innovative education must be able to provide students with critical thinking skills that are not only useful in mathematics, but also in various other disciplines (Innabi et al., 2020).

Diverse approaches, such as project-based learning, collaborative learning, and the use of information technology, are needed to achieve these goals. Project-based learning provides students with the opportunity to apply mathematical concepts in real-world situations, so that they can see the relevance of the knowledge they are learning. This activity encourages students to be actively involved, collaborate with peers, and communicate effectively, which are essential in developing social and emotional skills. In addition, the integration of information technology in learning allows students to access wider resources and conduct in-depth research. The use of relevant software and applications allows students to conduct simulations, visualizations, and experiments, making learning more interactive and interesting. Project-focused learning also helps students learn from mistakes, strengthening the process of reflection and self-evaluation. When students face challenges in the project, they are encouraged to find solutions independently or in groups, which increases their confidence and independence. Thus, innovative education is not only about transferring knowledge, but also about equipping students with the skills needed to think critically and creatively in dealing with problems. These skills will be very useful not only in academic contexts, but also in everyday life and the ever-changing world of work. Education that is able to integrate these various approaches will create a generation that is ready to adapt and innovate in the future.

The role of teachers as facilitators who create a conducive learning environment is also very important. Teachers not only function as conveyors of material, but also as directors who help students in the learning process. An atmosphere that supports open discussion and collaboration allows students to more freely explore ideas and deepen their understanding. The application of methods such as debate or case analysis encourages students to think critically, because they must consider various points of view and arguments. Modern education can help students develop critical thinking skills that will prepare them for an increasingly complex and dynamic world. Learning that involves reflection and self-evaluation is also very important. Students need to be trained to assess their thinking processes, identify biases, and understand how to make better decisions. Thus, students not only learn to solve problems, but also develop a constructive skeptical attitude and the ability to continue learning throughout life. These skills are not only relevant in academic contexts, but are also very necessary in everyday life and the ever-changing world of work.

Mathematics learning is often considered as a subject that only focuses on solving problems with established methods, without providing enough space for students to think creatively and critically. This view has the potential to hinder the development of higher-order thinking skills needed in various life contexts. Therefore, a more innovative and contextual approach is needed to improve the effectiveness of mathematics learning and develop students' critical thinking skills. Methods that connect mathematical concepts with real situations, the implementation of collaborative projects, and the use of

technology for experiments and simulations are part of this approach. Students not only learn to apply formulas or algorithms, but also understand the application of mathematical concepts in broader and more relevant contexts. Learning that encourages open discussion and critical reflection on various problem-solving methods can help students build a deeper and more flexible understanding of mathematics.

Innovative and contextual mathematics education will increase the effectiveness of learning and develop critical thinking skills that are very important for students' future lives and careers. Mathematics learning, if managed properly, can serve as an effective tool in honing students' critical thinking skills (Setiana et al., 2020). However, traditional learning methods that often only emphasize memorizing formulas and solving problems mechanically tend to limit the space for students to develop their critical thinking skills. The learning process that only focuses on the end result without paying enough attention to analysis, reflection, and evaluation can prevent students from achieving their best potential. The use of a more innovative and interdisciplinary approach in mathematics learning is very important. One approach that is now increasingly being used and has proven effective in facing this challenge is the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach. The STEAM approach integrates various disciplines to create a holistic and contextual learning experience. With this approach, students not only learn to understand mathematical concepts, but also how to apply them in real situations, think critically and creatively, and find innovative solutions to various problems.

The shift from traditional mathematics learning methods to the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach reflects an effort to improve the quality of teaching. Conventional methods, which often focus on memorizing formulas and mechanical procedures, can limit the development of students' critical thinking skills. As an alternative, the STEAM approach integrates multiple disciplines to create a more contextual and creative learning experience. This approach has the potential to improve critical thinking skills, but the results of its implementation vary across educational institutions. Some schools report significant improvements, while others face challenges in its implementation. This situation indicates the need for in-depth evaluation of the effectiveness of STEAM in mathematics learning and the importance of developing appropriate strategies for its implementation in the classroom. An approach that is increasingly being applied in education is STEAM (Science, Technology, Engineering, Arts, and Mathematics), which combines five core disciplines to create a richer and more diverse learning experience. By incorporating elements of art and technology into mathematics learning, students are faced with challenges that require creative and critical solutions. This makes the learning process not only more interesting but also relevant to real needs in everyday life. The STEAM approach encourages students to think beyond traditional disciplinary boundaries, allowing them to explore the connections between different fields of study. Students learn to integrate knowledge from different disciplines, which in turn enriches their understanding of the concepts being taught. This holistic learning experience is expected to equip students with the skills needed to adapt to an ever-changing world.

The application of the STEAM approach in mathematics learning can have a significant impact on students' critical thinking skills. Students not only learn mathematical concepts in the abstract, but also have the opportunity to apply that knowledge in relevant interdisciplinary projects. These projects encourage students to solve problems creatively and collaboratively, so they can directly feel the relevance of

mathematical concepts in real situations. Through collaboration, students learn to share ideas, listen to others' perspectives, and develop innovative solutions, all of which are important parts of critical thinking skills. In addition, these experiences build students' self-confidence, as they see that their approach to solving problems can make a real contribution.

STEAM-based learning not only builds academic knowledge, but also social and emotional skills that are important for future life. This study aims to explore the extent to which mathematics learning through the STEAM approach is effective in improving students' critical thinking skills. Through an analysis of the contribution of this approach to the development of critical thinking skills, this study is expected to provide in-depth insights into the application of STEAM in the context of education. The significance of this study lies not only in understanding how the STEAM approach can improve critical thinking skills, but also in preparing students to face an increasingly complex world. Education that integrates STEAM is expected to produce graduates who not only have strong academic knowledge, but also high adaptability and innovation. Graduates who have these skills are expected to be able to face global challenges, such as technological changes and evolving social needs, and are able to make positive contributions to society in the future. Through this study, it is also expected to provide guidance for educators in designing a more innovative and effective curriculum, so that education can answer the demands and needs of the times.

The application of the STEAM approach in mathematics learning provides students with the opportunity to explore abstract concepts in a more concrete and relevant way to their practical experiences. Through involvement in collaborative projects, students can learn from each other, hone interpersonal skills, and build effective collaboration. This activity also allows them to develop communication and negotiation skills, which are important skills in various social and professional contexts. The use of technology in STEAM projects not only makes the learning process more interesting, but also broadens students' horizons to the modern tools and resources available. By utilizing digital devices, students can access broader and more diverse information, and apply their knowledge in relevant contexts. Students are not only focused on applying mathematical formulas, but are also encouraged to innovate and find alternative solutions to the problems they face.

This not only boosts their self-confidence but also strengthens their motivation to continue learning and exploring new fields. The integration of the STEAM approach meets the demands of 21st-century education by focusing on developing critical thinking skills that are essential to facing future challenges. Through challenging projects, students become more interested in science and technology, which in turn prepares them to make positive contributions to society. This approach acts as an effective solution in developing critical thinking skills, as well as equipping students to become adaptive and innovative individuals in facing a changing world. In addition, STEAM-based education also helps students understand the importance of interdisciplinary collaboration, so that they can integrate the knowledge gained to solve more complex problems in real life.

METHODOLOGY

This study uses a literature study method to evaluate the effectiveness of mathematics learning with the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach in improving students' critical thinking skills. The research process begins with the identification and selection of relevant literature sources, such as

journal articles, books, research reports, and other academic publications. These sources are taken from academic databases such as Google Scholar with a focus on topics related to the application of the STEAM approach in mathematics learning and its impact on students' critical thinking skills. After the data was collected, the researcher conducted an in-depth analysis of each source, including a review of the methodology, sample size, and research results. Data from various studies were synthesized to identify patterns, similarities, and differences and to understand how the STEAM approach affects critical thinking skills. Evaluation of the quality and credibility of each source was carried out by assessing the methodology, data validity, and relevance to the research topic. The results of the literature analysis will provide insight into the effectiveness of the STEAM approach and offer recommendations for better implementation and suggestions for further research. The resulting research report will summarize the findings, analysis, and conclusions, as well as practical and academic implications, providing an in-depth understanding of the contribution of the STEAM approach to mathematics learning and improving students' critical thinking skills.

RESULTS AND DISCUSSION

The STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach has become increasingly popular in education because of its ability to combine five core disciplines to create richer and more varied learning experiences. By integrating elements of art and technology into mathematics learning, STEAM exposes students to challenges that require creative solutions and critical thinking, making the learning process more engaging and relevant to real-world demands. This approach also encourages students to think beyond the traditional boundaries of each discipline, explore the connections between fields, and apply the knowledge they learn in broader and more complex contexts. In mathematics learning, STEAM has a significant positive impact on students' critical thinking skills. They not only learn abstract concepts, but are also trained to apply that knowledge in interdisciplinary projects that require collaborative and innovative problem-solving skills. These projects provide students with the opportunity to combine aspects of science, technology, engineering, and the arts into one integrated learning framework, so that they can understand mathematics not only from a theoretical perspective, but also through its application in real life.

This study aims to explore the effectiveness of the STEAM approach in improving students' critical thinking skills. This study is expected to gain a deeper understanding of the role of STEAM in developing critical thinking skills and its impact on future educational practices. In addition, this study will also examine how the STEAM approach can prepare students to face global challenges through more relevant, creative, and flexible skills, as well as ways to implement this approach effectively in the educational curriculum. Thus, this study is expected to make a real contribution to improving innovative teaching methods and focusing on students' future needs. The STEM (Science, Technology, Engineering, and Mathematics) learning approach is a method that integrates science, technology, engineering, and mathematics, as stated by Winarni et al. (2016). According to Sanders (2009), integrative STEM education includes learning that involves at least two elements of STEM or connects one STEM element with other disciplines. The main objective of this approach is to link and integrate the knowledge gained in school with various aspects of real life, as explained by Izzati et al. (2019).

The STEM approach plays an important role in integrating mathematical concepts with the application of information technology to overcome various contextual problems

faced in everyday life. This is explained by Widana and Septiari (2021), who emphasize the importance of the theoretical relationship between mathematics and technology. The application of this approach allows students not only to understand the theory but also to apply it in real situations. The application of the STEM approach has proven effective in developing students' critical mathematical thinking skills, as stated by (Sumaji, 2019). In this context, students are trained to solve problems with a deep analytical approach, so that they are required to think logically and systematically. These skills are very essential, especially in an increasingly complex and dynamic world. The STEM approach also emphasizes the development of communication and collaboration skills, which are important aspects in the era of globalization and rapid technological advances, where individuals are expected to work together in teams to find innovative solutions. Therefore, students not only learn to solve problems individually but are also trained to collaborate and communicate effectively with others. This approach not only emphasizes mastery of academic concepts but also prepares students to face the challenges that exist in modern society.

Relevant and contextual learning experiences equip students to become adaptive and innovative individuals, able to face various challenges in everyday life. Effective implementation of the STEM approach is expected to increase the relevance of education to real-world needs and help students develop into lifelong learners who are ready to face the future (Molderez et al., 2018). Therefore, the STEM approach is not just a teaching method, but a holistic strategy that prepares students to play an active and productive role in society, and face complex global challenges with adequate skills. The STEM approach plays an important role in integrating mathematical concepts with the application of information technology to overcome various contextual problems faced in everyday life. This is explained by Widana and Septiari (2021), who emphasize the importance of the theoretical relationship between mathematics and technology. The application of this approach allows students not only to understand the theory but also to apply it in real situations. The application of the STEM approach has proven effective in developing students' critical mathematical thinking skills, as expressed by Sumaji (2019). In this context, students are trained to solve problems with a deep analytical approach, so that they are required to think logically and systematically. These skills are becoming increasingly essential, especially in an increasingly complex and dynamic world.

The STEM approach also emphasizes the development of communication and collaboration skills, which are important aspects in the era of globalization and rapid technological advancement, where individuals are expected to work together in teams to find innovative solutions. Therefore, students not only learn to solve problems individually, but are also trained to collaborate and communicate effectively with others. This approach not only emphasizes mastery of academic concepts, but also prepares students to face the challenges that exist in modern society. Relevant and contextual learning experiences equip students to become adaptive and innovative individuals, able to face various challenges in everyday life. Effective implementation of the STEM approach is expected to increase the relevance of education to real-world needs and help students develop into lifelong learners who are ready to face the future (Molderez et al., 2018). The STEM approach is not just a teaching method, but a holistic strategy that prepares students to play an active and productive role in society, and face complex global challenges with adequate skills.

The implementation of the STEAM (Science, Technology, Engineering, Arts, and Mathematics) model is strongly based on the concept of "habits of mind," which

emphasizes the importance of student involvement in the active learning process. In this context, students are encouraged to investigate and explore their surroundings through various practical activities that involve a hands-on approach. These activities not only improve their understanding of the concepts taught but also help them develop critical and creative thinking skills. The STEAM model aims to equip students with effective communication skills. Through activities that require them to convey their findings and ideas, students learn to express their thoughts clearly and persuasively. This process includes verbal presentations as well as the use of various tools and technologies to support communication. The implementation of the STEAM model not only focuses on mastering academic content but also on developing social and emotional skills that are essential for success in the real world (Hsiao et al., 2021).

Overall, the STEAM approach creates a dynamic and relevant learning experience, where students become active learners who are ready to face challenges in their environment. By prioritizing investigation, exploration, and communication, this model helps prepare students to become innovative and collaborative individuals, who are able to think critically and adapt in various situations. The STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach to mathematics learning has received widespread attention because of its ability to integrate various disciplines to improve the quality of learning. In the context of mathematics education, STEAM offers a more interactive, collaborative, and relevant method to the needs of students in the modern era. According to the literature, STEAM not only improves students' understanding of mathematical concepts but also encourages the development of critical thinking skills, which are very important in solving complex problems. Beers (2011) stated that STEAM encourages students' involvement in real-world problem-based projects, which strengthen the understanding of abstract concepts through concrete learning experiences. These projects encourage students to apply mathematical knowledge creatively and analytically, thereby improving critical thinking skills.

The STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach provides opportunities for students to develop critical thinking skills through project-based learning that integrates science, technology, and the arts (Herro et al., 2017). They found that students involved in the STEAM approach showed better abilities in analyzing mathematical problems and finding creative solutions compared to conventional learning methods. Baek et al. (2020) also highlighted that 80% of students involved in STEAM learning were able to identify mathematical problems in more depth and generate more than one creative solution. This study shows that STEAM encourages students to explore problems from multiple perspectives, both logically and aesthetically, which ultimately results in more varied and effective solutions. The STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach provides real-world relevance that helps students understand the importance of mathematics in everyday life (Land, 2023). By seeing direct applications of mathematics in technology, science, and the arts, students are more motivated to learn, thus increasing their emotional and intellectual engagement. Henricks (2018) added that the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach not only improves critical thinking skills but also develops students' creativity, especially through the integration of arts that encourages students to think flexibly and imaginatively.

The STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach is an effective learning approach in improving critical thinking skills, creativity, and student motivation in learning mathematics. The application of the STEAM (Science,

Technology, Engineering, Arts, and Mathematics) approach in learning mathematics can have a significant positive impact on students' critical thinking skills. By using this approach, students not only learn mathematical concepts abstractly, but also have the opportunity to apply that knowledge in interdisciplinary projects. These projects often involve combining mathematics with other fields, such as art design or technology, which require creative and collaborative problem solving. For example, in a project that links mathematics with art design, students can be asked to create geometric patterns or 3D models that utilize mathematical principles such as symmetry or proportion. According to Rahmazatullaili et al. (2017), project-based learning requires contextual problems related to real life in order to stimulate students' critical thinking skills. These problems are designed to encourage students to identify, explore, and put forward creative ideas in solving a problem.

This stage involves in-depth critical thinking exercises, including providing simple explanations and drawing conclusions based on the facts obtained. The ability to simplify complex information and draw appropriate conclusions is an important part of the decision-making process (Okoli et al., 2021). In addition, indicators of process skills that develop at this stage are observation skills, where students collect and analyze relevant facts from reliable sources related to the problem at hand. This observation ability includes the accuracy in assessing the validity of information and the skill of selecting relevant data to support the arguments or solutions proposed. The development of these skills not only strengthens students' critical thinking skills but also improves research skills that are essential in the context of learning and everyday life (Yang et al., 2022). Project-based learning plays an important role in preparing students to face complex future challenges that demand innovative solutions. Such projects help students understand how mathematical concepts are applied in creative contexts, while stimulating innovative thinking and unconventional solutions. Engaging in projects that link mathematics to technology, such as developing an app that uses mathematical algorithms, allows students to see firsthand the practical applications of mathematical concepts in modern technology. This process not only makes learning more engaging, but also makes it relevant to real-world needs and developments. In interdisciplinary projects, students are given the opportunity to collaborate in teams, so they can share ideas, discuss different approaches, and learn from each other. This activity is essential in developing communication and collaboration skills that are essential in the professional world.

Students are encouraged to think critically when faced with challenges that arise during the project, such as designing efficient algorithms or solving technical problems, so that they not only learn to apply theory but also develop the ability to analyze and evaluate various solutions. These projects enable students to understand the interconnectedness of various disciplines, including mathematics, science, and technology, which is essential to prepare them for the complex challenges of the modern world, where effective solutions often require a holistic and creative approach. The hands-on experience of completing the project gives students a sense of accomplishment and increases their motivation to continue learning. The application of mathematical concepts in real-world contexts teaches students to become independent and innovative problem solvers, and trains them to not only passively receive information but also actively engage in the process of creating solutions. These interdisciplinary projects contribute significantly to equipping students with the skills needed to adapt and innovate in the ever-evolving digital era.

Several significant barriers to implementing the STEAM approach need to be addressed, particularly related to teacher readiness and school infrastructure. Teacher

readiness to integrate aspects of arts, technology, and engineering into mathematics teaching is a major challenge. Many teachers struggle due to a lack of adequate training, which hinders their ability to implement this approach effectively (Chang et al., 2021). Without proper training, teachers may not fully understand how to integrate multiple disciplines, which can reduce the effectiveness of the STEAM approach. Limited technology facilities in some schools also contribute to the barrier. Schools with limited resources often do not have the necessary technology equipment, such as computers, specialized software, or engineering tools. These lack of facilities hinder the full implementation of the STEAM approach and can reduce the quality of implementation and outcomes in improving students' critical thinking skills. Research also shows that although there are improvements in students' critical thinking skills, these results are not always consistent across the student population. Variations in educational background, family support, and teaching quality across schools can affect outcomes. Schools with limited resources may not be able to achieve the same results as schools with more adequate facilities and support. To overcome these barriers, coordinated efforts are needed to provide better training for teachers, improve technology infrastructure in schools, and design more flexible and integrated curricula. Support from educational administration and policy is also important to ensure that all schools have equal access to the resources needed to implement STEAM approaches effectively (Allina, 2017).

Critical thinking is a cognitive ability that is very important for identifying and solving problems effectively. This ability plays a major role in formulating rational solutions and making the right decisions based on in-depth analysis. Khoiriyah (2018) explains that critical thinking not only helps in finding solutions but also in making logical and informed decisions. To evaluate whether a student has critical thinking skills, we can use several indicators. According to (Ennis, 2020) identified key indicators such as students' ability to provide clear and simple explanations, which reflect skills in conveying information in an easy-to-understand manner. Students must also be able to determine the basic skills needed to solve problems, demonstrating their understanding of the important elements in the process. The ability to draw conclusions based on available information illustrates students' skills in making logical decisions (Kalinowski, 2020). Further explanation of the reasons behind the decisions or conclusions taken shows the depth of students' understanding of the topic being discussed. Students are expected to be able to organize effective strategies and tactics in solving problems, which reflect their skills in planning and implementing optimal solutions (Ertmer et al., 2021). By utilizing these indicators, educators can effectively assess and develop students' critical thinking skills, which will ultimately improve problem-solving and decision-making skills in a variety of contexts.

The success of implementing the STEAM approach is highly dependent on several key factors, namely administrative support, availability of resources, and teachers' ability to manage interdisciplinary learning (Anisimova et al., 2022). Strong administrative support is essential to ensure that the implementation of the STEAM approach can take place effectively. This includes the provision of supportive policies, adequate budget allocation, and facilities that support STEAM activities (Kang, 2019). The availability of resources such as technological equipment and integrated learning materials also plays a crucial role. Schools need to provide adequate technological equipment, such as computers and software, and relevant materials so that teachers can implement STEAM learning in innovative and effective ways. Teachers' ability to manage interdisciplinary learning is an important factor. Teachers must receive ongoing training that includes

STEAM methodology, innovative teaching techniques, and strategies to overcome challenges in implementing this approach (Herro, 2021). Systematic integrated curriculum development is also an essential element to ensure that STEAM learning runs optimally (Jia et al., 2021).

The designed curriculum must be able to combine various disciplines harmoniously and relevant to the context of student learning. Collaboration between teachers, students, and schools is also very important. Active student involvement, parental support, and cooperation between teachers from various disciplines can increase the effectiveness of STEAM implementation and have a positive impact on improving students' critical thinking skills (Li et al., 2022). With a holistic and integrated approach, STEAM implementation can be carried out more effectively, producing optimal results in improving students' critical thinking skills. STEAM-based learning has a significant positive impact, especially in increasing students' interest in science and mathematics, as well as their ability to solve everyday problems (Adriyawati et al., 2020). This model not only emphasizes understanding scientific and mathematical concepts, but also encourages students to think creatively, explore, and be motivated to find new methods in solving various learning challenges (Khoir, 2021). In this approach, students are actively involved in the learning process, where the role of the teacher as a facilitator is very important to guide them when they face difficulties in solving problems.

Teachers act as guides who help students identify the steps needed to reach a solution, while creating a safe and supportive learning environment. Students feel more confident to explore new ideas and try different approaches to solving problems. The use of contextual problems that are relevant to everyday life is also key in STEAM-based learning. Students not only learn to apply theory, but also practice critical and analytical thinking, and are encouraged to ask questions, conduct research, and seek new information, making the learning process more interesting and meaningful. The implementation of the STEAM model at the elementary school level offers a varied learning experience, tailored to the needs and experiences of each student. This model integrates various disciplines—science, technology, engineering, arts, and mathematics—which helps students see the connections between these concepts in everyday life. This approach also facilitates the development of communication and collaboration skills, which are very important in today's globalized era. Although there are challenges in implementing STEAM learning, such as the often inadequate conditions of facilities and effective time management, efforts to overcome these problems will provide significant benefits for students.

STEAM learning can make students problem solvers, inventors, innovators, independent individuals, logical thinkers, and technology literate, enabling them to be better prepared for future challenges and connecting culture and history with STEAM education at the elementary school level (Ulfayani et al., 2022). Repetition and practice are needed so that students can develop critical and analytical thinking skills. Learning should begin by providing contextual problems that are relevant to the real world, so that through these problems, students can learn to solve problems and find new related information (Fatmawanti & Istihapsari, 2022). In practice at the elementary school level, student-centered STEAM learning offers a variety of learning experiences, tailored to the needs and experiences of each student. The STEAM model also applies a holistic approach that is influenced by the environment and social interactions, helping students determine the right actions in dealing with the available environment or objects, including adequate learning facilities (Nuragnia & Usman, 2021). The condition of facilities to

support the implementation of interactive media and furniture in the classroom is often inadequate in elementary schools. Another challenge faced is related to time management, where skills are needed to plan the time for each activity. There is also an assumption that the implementation of STEAM is theoretical, so it faces various challenges in the technical aspects of its implementation (Nuragnia & Usman, 2021). Ideally, STEAM learning should provide significant benefits to students, making them problem solvers, inventors, innovators, independent individuals, logical thinkers, technology literate, and able to connect culture and history with STEAM education at the elementary school level (Ulfayani et al., 2022).

The STEAM (Science, Technology, Engineering, Arts, and Mathematics) model can be applied to students in elementary schools because it has the potential to improve students' critical thinking, collaborative, and communication skills (Wannapiroon, 2022). This approach not only helps students analyze the information they have obtained but also contributes to the formation of strong character. The emphasis on developing these skills makes students better prepared to face challenges in their environment. The application of the STEAM model allows students to engage in more interactive and contextual learning activities, where they can apply the knowledge they have learned in real situations. Through projects involving various disciplines, students learn to collaborate and share responsibility in achieving common goals, which strengthens their social skills and improves their ability to work in teams, a skill that is very much needed in today's workforce.

STEAM-based learning also encourages students to ask questions, explore, and find creative solutions to problems they face, and teaches them to think critically, evaluate information, and make informed decisions. Students are faced with challenges that require analytical thinking, they learn to see multiple perspectives and consider alternative solutions. The STEAM model facilitates the development of effective communication skills, where students learn to convey their ideas clearly and persuasively. This makes them not only more confident in communicating, but also able to establish good relationships with peers and teachers. Through the implementation of the STEAM model, students are not only equipped with academic knowledge, but also skills that are very valuable for their future, trained to become adaptive and innovative individuals, and able to contribute positively to a society that continues to develop and face complex challenges. The implementation of the STEAM model in elementary schools is a strategic step in preparing the future generation to be ready to face an increasingly dynamic world.

The implementation of the STEAM model also contributes to increasing students' interest in science literacy. With the encouragement to find a balance between facts and reality, students are invited to be more active in the learning process, which allows them to find solutions to the problems they face. Project-based or problem-solving learning activities provide opportunities for students to conduct in-depth investigations, formulate questions, and seek relevant answers, thus encouraging curiosity (Chin, 2024). The STEAM model, students not only learn science and mathematics concepts, but also understand the application of these concepts in everyday life, so that they can see the relevance of education to the world around them. Collaboration with classmates in STEAM projects encourages students to learn to work together, respect the opinions of others, and develop important social skills. The implementation of the STEAM model in elementary schools not only equips students with academic knowledge but also prepares them to become individuals who are able to think critically, innovate, and contribute positively to society (Wilson et al., 2021). Through holistic and interactive learning experiences,

students are encouraged to engage in a dynamic learning process, where they can explore new ideas and apply knowledge in real-world contexts. Projects involving science, technology, engineering, art, and mathematics help students understand the interconnectedness of disciplines and enhance their ability to think across sectors. In addition, the implementation of the STEAM model serves to build important social skills, such as collaboration and communication, where students learn to work in teams, share ideas, and respect the views of others.

These experiences build students' self-confidence, encourage them to express their opinions and actively participate in discussions, both inside and outside the classroom. By encouraging students to solve problems creatively, the STEAM model provides them with the tools to innovate in facing future challenges. As students learn to see problems from different perspectives and find unconventional solutions, they are trained to become critical thinkers who can adapt to changes and technological advances. The success of the STEAM model is also reflected in students' motivation to continue learning and exploring the fields of science and technology. The interest generated from these fun and meaningful learning experiences will encourage students to pursue further education in these fields. Thus, the implementation of the STEAM model in elementary schools not only prepares students for academic challenges but also shapes the future generation who are ready to contribute significantly to an ever-evolving society.

Process skills refer to the abilities needed to develop intellectual, social, and physical skills that are rooted in the basic abilities that students already have. According to Kriswantorodkk (2021), process skills include various important abilities that support effective and applicable learning processes, integrating cognitive, social, and physical aspects. Some indicators of process skills include observation skills, namely paying attention to and recording important details in a situation or experiment. The ability to predict is also an important indicator, which involves making guesses based on existing data. Classification skills, which include grouping objects or information based on certain characteristics, and interpretation, which involve understanding and explaining the meaning of data or information, are also part of process skills (Zincs, 2020). Asking questions shows curiosity and a desire to understand more deeply, while the ability to propose hypotheses involves making guesses that can be tested. Experimental planning reflects the ability to organize steps to test a hypothesis or answer a research question. The skill of using tools and materials correctly is important for carrying out experiments or practical activities, while applying concepts means the ability to use theories or principles that have been learned in real situations (Brown, 2022). Communication skills include the ability to convey ideas, results, or information clearly and effectively to others. According to Rustam (2005), these process skill indicators are very important in supporting comprehensive learning, helping students develop their abilities in various aspects, and ensuring the application of knowledge and skills practically and productively.

CONCLUSION

The implementation of the STEM (Science, Technology, Engineering, Arts, and Mathematics) approach as stated in the results of the Systematic Literature Review (SLR) study shows that this approach has a significant positive impact on improving students' creative and critical thinking skills in mathematics. The STEM approach, which focuses on project-based learning and problem-solving, is very relevant to the project-based learning (PjBL) and problem-based learning (PBL) models. The integration of STEM with PjBL or PBL can be utilized by educators as an effective strategy to develop and hone students'

critical thinking skills and creativity in mathematics (Baharin et al., 2018). This approach can be applied in various contexts, both in small and large classes, and at various levels of education, from elementary school to college. The application of STEM at various levels of education provides opportunities for students to collaborate, innovate, and apply mathematical concepts in real situations that require problem solving (Sutaphan, 2019). This study has limitations that need to be noted, namely the lack of experimental studies that specifically explore the impact of STEM implementation on critical and creative thinking skills in the context of mathematics. This limitation creates opportunities for future researchers to conduct more in-depth and comprehensive studies, especially at the elementary and tertiary levels, so that they can provide new insights into the effectiveness of this approach. In addition, the results of this SLR study can be used as a basis for continuing research using a meta-analysis approach. Considering the various characteristics that have been discussed, this study is expected to produce stronger and more valid conclusions regarding the extent of the influence of the STEM approach in improving students' creative and critical thinking skills in mathematics. Through this effort, it is hoped that mathematics education can be transformed to be more innovative and relevant to the needs of the 21st century.

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