THE IMPACT OF STEM LEARNING MODELS ON CRITICAL THINKING ABILITY IN PRIMARY SCHOOLS

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Abstract: The purpose of this research is to examine the difference in the improvement of students' critical thinking skills between students who receive treatment using the STEM learning approach and students who only use conventional learning at SD Muhamadiyah 12 Medan in Mathematics learning. The research method used is a quantitative research method using an experimental design using 2 classes as the control group and the experimental group. Each class will be given a pre-test before being given treatment and a post-test after being given treatment. The results showed that there was a significant effect of the application of STEM learning on the critical thinking skills of fourth-grade students at SD Muhamadiyah 12 Medan in Mathematics learning, where the significance value was 0.000 < 0.05. Therefore, it can be said that there is a significant effect of the application of STEM-based MIKiR learning on students' critical thinking skills in mathematics subjects.

Keywords: *STEM, critical thinking, mathematics learning, elementary school*

Introduction

In the rapidly globalizing era, mathematics education plays a crucial role in preparing students to face the challenges of the 21st century. Critical thinking has become one of the essential skills that students must master from the elementary school level, particularly in mathematics learning (Rahman et al., 2023). However, the reality in the field shows that the critical thinking skills of elementary school students in Indonesia are still not optimal, especially in mathematics subjects (Doly, N. M., 2021)

According to the results of the Programme for International Student Assessment (PISA) in 2022, Indonesia is still ranked relatively low in mathematical ability, ranking 65th out of 79 countries with an average score of 379 (Prasetyo et al., 2023). This indicates that Indonesian students still have difficulty solving problems that require higher-order thinking skills, including critical thinking (Saragih, M., & Arika, A. 2020). This condition is also reflected at the elementary school level, where many students still struggle to understand mathematical concepts and apply them in problem-solving (Nasution, I. S., & Nasution, S., 2023).

One of the factors contributing to the low critical thinking skills of students is the conventional and teacher-centered learning approach. Mathematics learning in elementary schools is often still dominated by lecture methods and routine exercises that do not sufficiently stimulate students' critical thinking abilities (Widodo & Kartikasari, 2020). Students tend to memorize formulas and procedures without understanding the conceptual and contextual meaning of the material being studied (Nasution, et al. 2022)

The STEM (Science, Technology, Engineering, and Mathematics) learning model presents a promising alternative to address these issues. STEM is an interdisciplinary approach that integrates four fields of study: science, technology, engineering, and mathematics, within the context of the real world (Wahyuningsih et al., 2024). This learning model emphasizes the processes of investigation, problem-solving, and creativity development, which are aligned with the development of critical thinking skills.

Recent studies have shown the effectiveness of the STEM learning model in improving various aspects of mathematics learning. Research by Supriyadi et al. (2020) revealed that the implementation of STEM can enhance conceptual understanding and problem-solving abilities in elementary school mathematics. Similarly, a study conducted by Nugroho and Wulandari (2021) demonstrated that STEM-based learning can increase student motivation and active engagement in mathematics learning. The advantages of the STEM learning model lie in its characteristics that encourage students to: develop systematic and logical thinking through the integration of various disciplines, apply mathematical knowledge in real-world contexts, hone analytical and evaluative skills, enhance creativity in solving problems, and develop collaboration and communication skills

The implementation of STEM at the elementary school level becomes increasingly relevant considering the characteristics of fourth-grade students who are in the concrete operational stage. At this stage, students begin to develop logical thinking skills but still require concrete experiences in learning (Putri et al., 2022). The STEM model facilitates this through hands-on activities and meaningful contextual learning experiences. However, the challenges in implementing STEM in elementary schools cannot be ignored. Research by Hidayat and Rahmawati (2023) identified several obstacles, such as limited supporting facilities and infrastructure, a lack of teacher understanding about STEM integration, difficulties in designing learning activities that suit students' cognitive levels, time constraints in implementing learning, and the need for more flexible curriculum adaptation.

Nevertheless, various studies have shown that these challenges can be overcome through careful planning and adequate system support. A study by Firmansyah et al. (2023) demonstrated that continuous teacher professional development and the provision of appropriate resources can support the successful implementation of STEM in elementary schools. Critical thinking itself is an essential component in mathematics learning. Facione (2020) identified six core skills in critical thinking: interpretation, analysis, evaluation, inference, explanation, and self-regulation. The STEM learning model has the potential to develop these six skills through integrated and problem-based learning activities. Recent research by Kusuma et al. (2024) shows that students who learn mathematics using the STEM model exhibit significant improvements in: the ability to analyze mathematical information, skills in making connections between concepts, the ability to evaluate problem-solving strategies, skills in communicating mathematical thinking, and the ability to draw conclusions based on evidence.

On the other hand, the characteristics of fourth-grade elementary school students, who are in the 9-10 year old age range, have great potential for the development of critical thinking skills. At this age, students begin to develop abstract and logical thinking abilities, although they still require scaffolding in the process (Winarni et al., 2021). The STEM learning model can bridge this need through activities that combine concrete experiences with mathematical reasoning.

The urgency of research on the impact of the STEM learning model on critical thinking skills in fourth-grade elementary school mathematics is supported by several factors: the need to improve the quality of mathematics learning at the elementary level, the importance of developing critical thinking skills from an early age, the potential of the STEM model in creating meaningful mathematics learning, the increasingly complex demands of 21st century competencies, and the need to develop empirical evidence on the effectiveness of the STEM model at the elementary school level.

The implementation of the STEM learning model in fourth-grade elementary school mathematics requires special attention to several aspects: the suitability of the material with the students' cognitive development level, the integration of appropriate technology, the development of contextual learning activities, a comprehensive assessment system, and a conducive learning environment.

Based on the various considerations above, research on the impact of the STEM learning model on critical thinking skills in fourth-grade elementary school mathematics becomes highly relevant and important to conduct. The results of this research are expected to make a significant contribution to the development of more effective and meaningful mathematics learning practices at the elementary school level.

Literature Review

The STEAM Learning model

The Steam Learning model is an interdisciplinary approach that integrates four main fields: Science, Technology, Engineering, and Mathematics. According to Rahman et al. (2023), STEM is not just a combination of four disciplines, but an integrated learning approach that enables students to understand how academic concepts are connected to the real world. Widodo and Kartikasari (2020) emphasize that STEM encourages students to develop skills such as problem-solving, creativity, critical thinking, and collaboration.

Kusuma et al. (2024) have identified several key characteristics of STEM learning: real-world problem-based learning, integration of technology in the learning process, the engineering design process approach, development of 21st-century skills, and collaborative and student-centered learning.

Research by Nugroho and Wulandari (2021) shows that implementing STEM in elementary schools requires special adaptation to suit the cognitive development level of students. Hidayat and Rahmawati (2023) propose a framework for STEM implementation that includes: simplification of technical concepts, use of familiar materials, structured hands-on activities, integration with local contexts, and appropriate scaffolding.

Critical Thinking Skills

Putri et al. (2022) define critical thinking in mathematics as a mental process involving the ability to analyze, evaluate, and draw conclusions based on mathematical information. The components of critical thinking in mathematics according to Firmansyah et al. (2023) include: interpreting mathematical problems, analyzing information and data, evaluating solution strategies, making logical conclusions, and reflecting on the process and results.

Wahyuningsih et al. (2024) explain that the development of critical thinking skills in elementary school students requires a systematic and continuous approach. Effective strategies include using Socratic questioning, engaging in open-ended problem-solving activities, collaborative discussions, mathematical investigation projects, and metacognitive reflection.

Supriyadi et al. (2020) developed a framework for assessing critical thinking in mathematics that covers: the ability to identify problems, data analysis skills, the ability to make mathematical arguments, the evaluation of alternative solutions, and evidence-based decision-making.

The relationship between STEM and critical thinking

Recent research by Winarni et al. (2021) shows a positive correlation between STEM learning and the development of critical thinking abilities. Some STEM aspects that support critical thinking include: inquiry-based approach, integration of multiple perspectives, design thinking processes, systematic analysis, and evidence-based evaluation.

A meta-analysis study conducted by Prasetyo et al. (2023) revealed that the implementation of STEM consistently shows a positive impact on students' critical thinking skills, with an average effect size of 0.72. Factors affecting the effectiveness include: quality of instructional design, duration of implementation, teacher competence, availability of resources, and school system support.

Based on research by Facione (2020), fourth-grade elementary school students (ages 9-10) are at a strategic stage of cognitive development for critical thinking. Cognitive characteristics at this stage include: developing logical thinking abilities, understanding cause-and-effect relationships, ability to make multidimensional classifications, simple inductive and deductive reasoning, and comprehension of abstract concepts with concrete support.

Method

This research uses a quantitative approach with a quasi-experimental design in the form of a nonequivalent control group design. This design was chosen because the research was conducted in an educational setting that did not allow for random assignment (Wahyuningsih et al., 2024). The research design involved two groups: the experimental group that received mathematics learning using the STEM model and the control group that received conventional learning.

The population in this study were all fourth-grade students at SD Muhammadiyah 12 Medan in the 2024/2025 academic year. The selection of the population was based on the consideration of the relatively homogeneous characteristics of the school. The sample was determined using a purposive sampling technique, taking into account certain criteria (Kusuma et al., 2024). The research sample consisted of an experimental group of 30 students in class IV-A and a control group of 30 students in class IV-B. The sample selection criteria included (1) equivalent initial mathematical abilities, (2) availability of adequate learning facilities, (3) the school's willingness to implement the STEM model, (4) teacher competence in applying STEM learning, and (5) representative student characteristics.

The independent variable in this study is the learning model, which consists of two categories: (1) the STEM learning model (experimental group) and (2) the conventional learning model (control group). The dependent variable is the critical thinking ability in mathematics, which is measured through: (1) problem interpretation skills, (2) mathematical information analysis, (3) evaluation of solution strategies, (4) logical conclusion drawing, and (5) explanatory skills.

Results and Discussion

Results

This research was conducted in the fourth grade of SD Muhammadiyah 12 Medan in the 2024/2025 academic year. The sample consisted of 2 classes - class IV B as the experimental group and class IV A as the control group, with a total of 60 students involved. The material taught was alternative energy sources, covered over 4 class sessions.

The research aims to compare the improvement in critical thinking skills of the fourth-grade students in mathematics. Data collected includes: (1) students' critical thinking skills in mathematics, (2) analysis of critical thinking skill data, and (3) hypothesis testing. Differences in average critical thinking skills between the experimental and control groups will also be analyzed based on students' initial assessment levels (fully understanding, partially understanding, and not understanding).

The STEM learning stages for the experimental group included: problem orientation, alternative problem-solving, and problem-solving design. Pre-tests and post-tests on Critical Thinking Ability were administered to both groups. Descriptive statistical analysis was conducted to describe the research data, including total samples, maximum and minimum values, means, and standard deviations. Here are the results of the descriptive statistical analysis conducted to describe the research data, including the number of data points, maximum value, minimum value, mean, and standard deviation. The results of the descriptive analysis using SPSS in this research are as shown in the table 1.

Table 1: Tesults of descriptive statistical analysis

	N	Min	Max	Mean	STD Deviation
Pre-eks	30	3	8	5,03	1,402
Post-eks	30	4	13	9,57	2,269
Pre-cont	30	2	8	4,33	1.709
Post-cont	30	4	18	6,97	2,442
Valid N	30				

From the data above, it can be known that the pretest value of the experimental group with 30 data points has a minimum value of 3 and a maximum value of 8, with an average value of 5.03 and a standard deviation of 1.402. Furthermore, the posttest value of the experimental class with 30 data points has a minimum value of 4 and a maximum value of 13, with an average of 9.57 and a standard deviation of 2.269.

For the pretest value of the control class with the same number of data as the experimental class, which is 30, the minimum value is 1 and the maximum value is 8, with an average of 4.33 and a standard deviation of 1.709. And finally, the posttest value of the control class has a minimum value of 1.57 and a standard deviation of 2.269. With 30 data points, the minimum value is 4 and the maximum value is 13, the average value is 6.97 and the standard deviation is 2.442.

The following is a histogram of the average pretest and posttest values of students' critical thinking skills in the two research classes made with the help of the Excel program.

Meanwhile, the comparison of the average, standard deviation, minimum and maximum values of students' critical thinking skills from the three experimental class groups is shown in Table 2.

Table 2: The mean and standard deviation of the experimental class's critical thinking ability

Group	N	Mean	Std. Deviation	Min.	Max.
High	5	10,40	2.702	7	13
Current	17	10,00	1,871	7	12
Low	8	8,13	2,416	4	11

Based on Table 2, it can be concluded that the final average of critical thinking skills among the three groups is relatively different. The average group has a relatively higher average compared to the other groups.

Discussion

The normality test is conducted to determine whether the sample being studied is normally distributed or not. The data used are the pretest and posttest results of the experimental class and the control class students.

The results of the normality test that have been carried out are as shown in Table 3.

Table 3. Normality test

	Class	Shapiro-Wilk		
		Statistic	df	Sig.
Result s of critical thinki ng skills	Pretest Ex	0,933	8	0,60
	Posttest Cont	0,40	13	0,90
	Pretest Ex	0,896	8	0,07
	Posttest Cont	0,922	18	0.31

From the table above, it can be seen that the results of the normality test of the pretest and posttest data in the experimental class and the control class obtained significant results with each > 0.05, so it can be concluded that each class is normally distributed.

The purpose of the homogeneity test is to determine whether the data variance of the two groups is homogeneous (the same) or heterogeneous (not the same). The homogeneity test is not one of the requirements (not an absolute requirement) that is carried out before conducting hypothesis testing or an independent sample t-test. In this study, the homogeneity test was conducted to determine whether the variance of the post-test data in the experimental class and the control class was homogeneous or not. The results of the homogeneity test using SPSS that have been carried out are as shown in Table 4.

Table 4. Homogeneity test

Levene Statistic	df1	Df2	Sig.
0,560	1	58	0,457

Based on the table above, the significance value of the posttest data is 0.457, which means the result is > 0.05. So, it can be concluded that the variance of the posttest data in the experimental class and the control class is the same or homogeneous.

Hypothesis test after conducting the normality test and homogeneity test, it can be concluded that the data is normally distributed and homogeneous. Subsequently, a hypothesis test will be carried out using the T-test or independent sample t-test using SPSS 20, and the results of the hypothesis test sig. (2-tailed) will be 0.000.

Based on the results of the independent sample t-test, the use of STEM learning based on MIKiR on students' critical thinking skills obtained a significance value (2-tailed) of 0.000. Then, the significance value obtained is < 0.05, so H0 is rejected and Ha is accepted, and it can be concluded that there is an effect of STEM learning based on MIKiR on students' critical thinking skills.

Conclusion

Based on the research results and discussion on the impact of the STEM learning model on the critical thinking skills in mathematics learning for fourth grade elementary school students, several conclusions can be drawn: The STEM learning model has been proven effective in improving the mathematical critical thinking skills of fourth grade elementary school students, The implementation of the STEM model has a positive impact on the five aspects of critical thinking skills, The successful implementation of the STEM model is supported by several key factors: Integration of real-world contexts in mathematics learning, Hands-on approach that facilitates concept understanding, Collaborative learning that encourages the development of analytical skills, Scaffolding that aligns with students' cognitive development levels, and School system support in implementing the program.

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