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ENHANCING STUDENTS' MATHEMATICAL CRITICAL THINKING SKILLS THROUGH STEM LEARNING ON JUNIOR HIGH SCHOOL

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ABSTRACT

This study aims to Enhancing Students' Mathematical Critical Thinking Skills Through Stem Learning On Junior High School. Critical thinking is an essential component in mathematics education, as it equips students with the ability to solve real-world problems, analyze data, and develop deeper conceptual understanding. The study adopts a quasi-experimental design with a pretest-posttest control group, involving seventh-grade students from SMPIT Mentari Ilmu. The experimental group (VII Shofiyyah) was taught using STEM-based learning, while the control group (VII Khaula) received conventional instruction. Both groups were assessed through pretests and post-tests to evaluate improvements in critical mathematical thinking skills. The data were analyzed using descriptive statistics, normality tests, and independent t-tests to determine the significance of the results. Findings indicated that the experimental group significantly outperformed the control group, with higher post-test scores reflecting greater improvement in critical thinking skills. Moreover, the students and teachers expressed positive responses to the STEM-based approach, highlighting its effectiveness in fostering engagement and higher-order thinking. The study concludes that STEM-based learning serves as an effective pedagogical strategy for enhancing critical thinking in mathematics, making it a valuable tool for junior high school education. The results suggest that this approach should be further developed and implemented to promote students' critical thinking abilities in various educational contexts.

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INTRODUCTION

In the contemporary era, mathematical critical thinking skills are among the most crucial competencies that must be cultivated in junior high school students (Setiawan, 2015). These skills encompass a range of abilities, including conceptual understanding, strategic competence, and problem-solving abilities. Nevertheless, empirical evidence indicates that the majority of junior high school students in Indonesia still exhibit a deficiency in their mathematical critical thinking abilities (Setiawan, 2015). To address this issue, a learning approach that can enhance students' mathematical critical thinking skills is required. One potential strategy to improve junior high school students' mathematical critical thinking abilities is STEM-based learning. STEM-based learning offers students the opportunity to learn mathematics in a real-world context, which can facilitate the development of a more profound conceptual understanding. This approach also affords students the opportunity to apply mathematical concepts in solving real-world problems.

Gokhale (in Hendriana et al., 2021) posited that critical thinking can be defined as a cognitive process that encompasses analysis, synthesis, and evaluation of concepts. In the context of critical thinking, individuals engage in the act of processing existing data or information to derive deeper meaning. As defined by Rudiatmoko (2023), critical reasoning is the capacity to engage in deep analysis of information, meticulous assessment of arguments, identification of underlying assumptions in a statement, and the formulation of decisions based on mature and reflective thinking. Ennis (in Hendriana et al., 2021) posits that critical thinking is reflective thinking accompanied by reasons, with the objective of determining what is believed or applied through five key ideas, including practical, reflective, reasonable, trust, and action. In light of the insights offered by experts in the field, it can be posited that mathematical critical thinking is a cognitive ability that encompasses the processes of analysis, synthesis, and evaluation of concepts within the context of mathematics. It encompasses the capacity to investigate information in depth, to assess arguments with care, to identify the underlying assumptions of statements, and to make decisions based on mature and reflective thinking. In particular, mathematical critical thinking equips students with the capacity to make well-informed and accurate decisions, while also enabling them to adjust their attitudes in accordance with logical reasoning within the domain of mathematics.

In a study conducted by Indriyanti et al. (2018), there are a number of indicators that include: a) interpretation, b) analysis, c) presenting information in depth, d) evaluation, and e) drawing conclusions. In the study conducted by Prameswari et al. (2018), the indicators used include presenting definitions and concepts, recognizing assumptions, and determining the method to be used. Indicators of critical thinking skills according to Ennis (Sofri et al., 2020) are as follows:

1) Basic Clarification, which consists of formulating a question, analyzing arguments, and asking and answering clarification questions.
2) Making decisions, consisting of considering the credibility of a source, observing and considering the results of observations.
3) Inference, consisting of making deductions and considering the results of deductions, making inductions and considering the results of inductions, and making and considering the value of decisions.
4) Advanced Clarification, consisting of identifying terms and considering definitions, and referring to unstated assumptions.
5) Assumption and Integration, which consists of considering and reasoning logically about premises, reasons, assumptions, other positions, and proposals and incorporating other skills and dispositions in making and defending a decision.

STEM, introduced by the United States, is an approach that integrates today's STEM education (Science, Technology, Engineering and Mathematics) into a learning option capable of shaping a generation ready to face the various challenges of the 21st century. STEM is an approach to learning that combines two or more of the scientific disciplines included in STEM, and/or between the scientific disciplines included in STEM and one or more other school subjects (Sanders, 2009). In the view of Mulyani (2019), STEM is defined as a "bridge" that connects educational institutions, such as schools, with the reality of the surrounding world. The STEM approach is expected to be an effective link between the context of learning in educational institutions and its practical application in real life. According to Kurniawan and Susanti (2021), STEM-based learning can be implemented through various models such as cooperative learning, PBL (problem-based learning), PJBL (project-based learning), and other specific learning approaches.

Based on Futurelearn (Kurniawan & Susanti, 2021), STEM learning aims to develop seven skills in students, namely the development of critical thinking skills, independent learning, the ability to communicate and collaborate during the learning process, digital literacy, problem solving skills, creativity, and the ability to self-reflect. It can be concluded that STEM not only provides theoretical understanding, but also develops practical skills necessary for students to face complex challenges in the real world.

Table 1. The Role of Each STEM Element in Learning (Farwati, 2021)

STEM elements	Description
Science	Problems in daily life that are addressed in learning.
Technology	Tools used when learning takes place. Can be a source of learning for students such as cell phones, laptops, google, youtuhe, etc.
Engineering	Learning steps or student activities by following the engineering process steps. Namely: Problem identification, problem analysis, initiation of problem-solving ideas, problem-solving design, testing, and communication of test results.
Mathematics	Measurement, calculation, comparison, and other mathematical activities that students perform during the learning process in accordance with the learning objectives to be achieved.

The steps of STEM learning and learning activities according to Kurniawan & Susanti (2021) consist of: a) hands-on activities; b) mimicking real-life scenarios; c) integrating mathematics and science in projects. In addition, the most important parts that need to be considered for STEM learning to be of high quality are as follows: a) Design focus; b) Active application; c) Integration. According to through Rahmawati et al. (2022) the STEM approach, students' creativity is developed so that they are able to solve problems in everyday life and can reason and think critically, logically, and systematically.

The development of mathematical critical thinking skills is an important objective in mathematics education. These skills can be built according to the ability of students through the learning of mathematical facts, concepts, principles, and skills. Therefore, in learning mathematics, it is necessary to employ strategies that facilitate the understanding of students. One strategy for enhancing students' mathematical critical thinking abilities is through STEM-based learning (Rahmawati et al., 2022). The development of critical thinking skills is essential for students to achieve effective decision-making processes. These skills are invaluable for navigating the challenges of modern life and preparing for an uncertain future. Students with well-developed critical thinking abilities are able to approach problems systematically, confront diverse challenges in a structured manner, generate innovative questions, and design solutions that are relatively novel (Johnson, 2007). However, empirical evidence from the field suggests that the importance of critical thinking skills is not universally acknowledged. For instance, research conducted by Susilawati et al. (2017) revealed that 61% of students exhibited low levels of critical thinking skills, while 15% demonstrated very low levels. Moreover, research conducted by Hidayanti et al. (2016) demonstrated that students' critical thinking skills remained suboptimal in the domains of identification, evaluation, and inference.

Furthermore, at SMPIT Mentari Ilmu, the results of the 2023 education quality report card indicated that the numeracy ability indicator, which assesses the proportion of students who are able to reason to solve complex and non-routine problems based on their mathematical concepts, achieved a score of 53.33%. In the critical reasoning indicator, which assesses the willingness and habit of making logical decisions based on various evidence and diverse points of view, the score was 55.8%. This indicates a need for improvement in students' critical thinking skills. STEM-based learning can facilitate the development of students' mathematical critical thinking skills. According to Purnamasari et al. (2020), STEM emphasizes the problem-solving process, encouraging creative and critical thinking. In addition, STEM-based learning engages students in activities that cultivate critical thinking skills, including analysis, synthesis, and evaluation. This can facilitate the development of strategic competencies in solving mathematical problems in a more creative and innovative manner. With appropriate implementation, STEM-based learning has the potential to significantly enhance junior high school students' mathematical critical thinking abilities. It is therefore important to continue to develop and implement this learning approach in order to provide maximum benefits for the development of mathematical critical thinking skills of junior high school students.

Based on the background of the problems described, the problems in this study are formulated and limited as follows:

1. Is there an increase in mathematical critical thinking skills of junior high school students whose mathematics learning using science, technology, engineering, mathematics (STEM) based learning is better than those using ordinary learning?
2. How is the effectiveness of science, technology, engineering, mathematics (STEM)-based learning in improving mathematical critical thinking skills of junior high school students?
3. How do students and teachers respond to the implementation of science, technology, engineering, mathematics (STEM) based learning in Mathematics learning?

METHOD

In this study, the method to be used is the quasi-experimental method. The quasi-experimental method is a research method used to obtain information that is an approximation of the information that can be obtained from actual experiments in situations where it is not possible to control or manipulate all relevant variables. This method is used because it is not possible to take random subjects from the population, this is because the research subjects have naturally formed in a group (class). Even so, the purpose of the study, which is to know the cause-and-effect relationship between existing variables, can still be seen.

The research design used is the nonequivalent group design, according to Sugiyono (2013), this design is almost the same as the pretest-posttest control group design, only in this design, the experimental group and control group are not randomly selected. Before treatment, both classes were given a pretest to assess the initial situation and to detect differences between the experimental and control classes (Sugiyono, 2013). The experimental class was treated with STEM learning in class VII Shofiyah, while the control class continued with ordinary learning in class VII Khaula. After the treatment was completed, both were subjected to a post-test.

Table 2. Nonequivalent Group Design

Class	Pretest	Treatment	Posttest
Experiment	O_1	X	O_2
Control	O_3	C	O_4

Description:
O_1= Pre-test / initial test before receiving treatment in the experimental class.
O_2= Post-test / final test after receiving treatment in the experimental class.
O_3= Pretest/initial test before being given ordinary learning in the control class..
O_4= Posts / final test after receiving ordinary learning in the control class.
X = Learning treatment with STEM
C = Ordinary learning

RESULTS AND DISCUSSION

Results

Table 3. The Results of the Normality Test from the Post-Test

Tests of Normality

Kelas		Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
Nilai	Kelas Eksperimen	.137	24	.200*	.938	24	.151
	Kelas Kontrol	.119	23	.200*	.965	23	.576

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Based on table 3, the Shapiro-Wilk results, the Sig value of the experimental class is 0.151 and the Sig value of the control class is 0.576. Since the Sig value of both classes is greater than 0.05, it can be concluded that both data are normally distributed, so the requirements for the independent t-test are met. Next, the independent t-test steps are performed.

$$H_0 : \mu_1 = \mu_2$$

The initial critical thinking ability of junior high school students whose mathematics learning uses STEM learning is the same as the initial higher order thinking ability of junior high school students who use ordinary learning.

$$H_a : \mu_1 \neq \mu_2$$

The initial higher order thinking ability of junior high school students whose mathematics learning uses STEM learning is not equal to the initial higher order thinking ability of junior high school students who use ordinary learning.

Table 4. The Results of the Descriptive Statistics of Post-Test Data

Group Statistics

Kelas		N	Mean	Std. Deviation	Std. Error Mean
Nilai	Kelas Eksperimen	24	41.41	10.369	2.117
	Kelas Kontrol	23	30.27	11.810	2.463

Based on the table 4, the average of the experimental class is 41.44 and the average of the control class is 30.27. Descriptively, it can be concluded that there is a difference in the average value of the statistics between the experimental class and the control class. To prove whether the difference is significant or not, it can be seen in the 2nd output.

Table 5. Results of the Independent Samples T-Test of Post-Test Data

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Nilai	Equal variances assumed	.008	.929	3.439	45	.001	11.135	3.238	4.613	17.656
	Equal variances not assumed			3.429	43.699	.001	11.135	3.247	4.589	17.680

Based on table 5, the Sig Levene's test for equality of variance of 0.929> 0.05 is obtained. This means that the variance of the data between the experimental class and the control class is homogeneous, so the interpretation of the output table of the Independent Samples Test is guided by the equal variances assumed for the Sig (2-tailed) value, which is 0.001 <0.05. Based on this, it can be concluded that H_0 is rejected, which means that the initial critical thinking ability of junior high school students whose mathematics learning uses STEM-based learning is not the same as the initial critical thinking ability of junior high school students who use ordinary learning.

Since the results of the analysis of the initial ability pretest data are different, the calculation of N gain is carried out to determine whether STEM-based learning is better than ordinary learning.

$$N - Gain = \frac{postes - pretes}{SMI - Pretes}$$

There is a hypothesis for this test to see the increasment of students' mathematical critical thinking skills after being teached by STEM learning, the hypothesis test is:

$$H_0: \mu_1 > \mu_2$$

The higher-order thinking ability of junior high school students who learn mathematics using the contextual approach supported by Geogebra is better than that of students who learn mathematics using the conventional approach.

$$H_a: \mu_1 \leq \mu_2$$

The higher-order thinking ability of junior high school students whose mathematics learning uses a contextual approach supported by Geogebra is not better or equal to the higher-order thinking ability of junior high school students who use ordinary learning.

Then the t-test is performed by SPSS. The following data were obtained:

Table 6. Results of the T-Test N-Gain

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
N_GAIN	Equal variances assumed	4.561	.038	1.351	45	.183	.07629	.05645	-.03740	.18998
	Equal variances not assumed			1.341	39.017	.188	.07629	.05688	-.03876	.19133

Discussions

Based on the output results, the Sig Levene's test for equality of variance of 0.038 <0.05 is obtained. This means that the data variance between the experimental class and the control class is NOT HOMOGENIC, so the interpretation of the output table of the Independent Samples Test is guided by equal variances not assumed for the Sig (2-tailed) value, which is 0.188. Since the hypothesis formulated is a one-tailed hypothesis, then $\frac{sig\ (2-tailed)}{2} = \frac{0.188}{2} = 0.094$. Since $0.094 > 0.05$, it can be concluded that H_0 is accepted, which means that junior high school students whose mathematics learning uses STEM-based learning is more than those who use ordinary learning. The effectiveness of STEM-based learning in improving critical thinking skills can be seen from the completeness of students' learning outcomes as follows. Looking at the completeness of the experimental class, there were 23 students who scored ≥ 75, or as many as 95.83% of the students who were complete, and 1 student who scored < 75, or as many as 4.17% of the students who were not complete. Looking at the completeness of the control class, there were 15 students who scored ≥ 75, or up to 65.21% of the students who were complete, and 8 students who scored < 75, or up to 34.79% of the students who were not complete.

Based on the results obtained, each statement is in the good and very good categories, and the overall presentation in the very good category is 83%, so the students' responses to learning can be said to be very good. While in the teacher's response, each statement is in the good category, and the overall presentation in the good category is 76%, so the teacher's response to learning can be said to be good.

The results of this study are consistent with the findings of Farwati (2021), which state that STEM education supports independent learning and student engagement, as well as improves learning outcomes. Similarly, Kurniawan & Susanti (2021) found that STEM-based mathematics instruction positively impacts problem-solving abilities and academic achievement. However, the study by Hidayanti et al. (2016), which investigated inquiry-based learning, indicated that improvements in critical thinking skills may not always be accompanied by significant increases in academic achievement compared to STEM-based learning. The differences in effectiveness can be influenced by various factors, such as the implementation of STEM methods, student backgrounds, or variations in classroom environments. Mulyani (2019) demonstrated that STEM approaches are effective in addressing the challenges of the Fourth Industrial Revolution by integrating practical and theoretical knowledge. This study supports our findings, indicating that STEM approaches might be more suitable in the context of modern education. Conversely, Sugiyono (2013) emphasizes the need for tailored implementation strategies to maximize the benefits of STEM, which may explain variations in research outcomes.

CONCLUSION

STEM-based learning is better than ordinary learning. The results obtained when viewed from the completeness of the experimental class the difference is 30.62% higher, so that the use of the STEM approach is effective in improving the mathematical critical thinking skills of junior high school students. Based on the results obtained, each statement is in the good and very good categories, and the overall presentation in the very good category is 83%, so the students' responses to learning can be said to be very good. While in the teacher's response, each statement is in the good category, and the overall presentation in the good category is 76%, so the teacher's response to learning can be said to be good.

This research provides valuable insights into the effectiveness of STEM-based learning in enhancing students' academic performance and offers additional evidence of the benefits of this approach in mathematics education. The findings may encourage broader adoption of STEM methods within mathematics curricula and other educational contexts. The contribution of this study also lies in highlighting the importance of teaching methods that align with current educational needs and challenges. This study has several limitations, including a limited sample size and potential variations in the implementation of STEM-based learning across different classrooms. Additionally, the study did not evaluate the long-term effects of the learning method on students' critical thinking abilities. Further research with larger sample sizes and longer duration is needed to gain a deeper understanding of the effectiveness of STEM-based learning.

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