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EFFECT OF SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM) ON THE HIGHER ORDER THINKING SKILL (HOTS) OF ELEMENTARY SCHOOL STUDENTS

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ABSTRAK

Model pembelajaran Science, Technology, Engineering, and Mathematics (STEM) merupakan pendekatan yang efektif untuk meningkatkan keterampilan abad ke-21. Sejumlah penelitian menunjukkan bahwa model ini mampu mengembangkan keterampilan berpikir tingkat tinggi (*Higher Order Thinking Skills* / HOTS), hasil belajar, kreativitas, dan inovasi siswa. Penelitian ini merupakan penelitian kuantitatif dengan desain kuasi-eksperimen, menggunakan rancangan kelompok kontrol pretest–posttest yang tidak ekuivalen. Teknik pengambilan sampel yang digunakan adalah simple random sampling. Populasi penelitian mencakup seluruh siswa kelas V di Kabupaten Mejobo yang tersebar di 46 sekolah dasar. Sampel penelitian terdiri dari 34 siswa kelas V SD 5 Jepang dan 35 siswa kelas V SD 1 Kasil sebagai kelas eksperimen, serta 31 siswa kelas V SD 2 Jepang sebagai kelas kontrol. Teknik pengumpulan data meliputi wawancara, tes, dan dokumentasi**.** Hasil analisis menunjukkan bahwa penerapan model pembelajaran STEM berpengaruh positif terhadap kemampuan HOTS siswa, dengan nilai t-hitung sebesar 2,9 > t-tabel 2,0 dan peningkatan skor rata-rata sebesar 58,9%**.** Berdasarkan hasil penelitian ini, dapat disimpulkan bahwa model pembelajaran STEM berpengaruh signifikan dalam meningkatkan kemampuan berpikir tingkat tinggi siswa sekolah dasar kelas V.

Kata kunci: Ilmu Pengetahuan, Teknologi, Teknik, dan Matematika (STEM), Keterampilan Berpikir Tingkat Tinggi (HOTS)

ABSTRACT

The Science, Technology, Engineering, and Mathematics (STEM) learning model is an effective approach to improving 21st-century skills. Several studies have shown that this model is able to develop students' Higher Order Thinking Skills (HOTS), learning outcomes, creativity, and innovation. This study is a quantitative study with a quasi-experimental design, using a non-equivalent pretest–posttest control group design. The sampling technique used was simple random sampling. The study population included all fifth-grade students in Mejobo Regency spread across 46 elementary schools. The study sample consisted of 34 fifth-grade students of SD 5 Jepang and 35 fifth-grade students of SD 1 Kasil as the experimental class, and 31 fifth-grade students of SD 2 Jepang as the control class. Data collection techniques included interviews, tests, and documentation. The results of the analysis showed that the implementation of the STEM learning model had a positive effect on students' HOTS abilities, with a t-test value of 2.9 > t-table 2.0 and an average score increase of 58.9%. Based on the results of this study, it can be concluded that the STEM learning model has a significant effect on improving the high-level thinking skills of fifth-grade elementary school students.

Keywords: *Science, Technology, Engineering,Mathematics (Stem), Higher Order Thinking Skill (Hots)*

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Introduction

The challenges of the development of 21st century life demand individuals to possess high-level thinking skills to adapt to rapid technological advancements. The use of technology has become an obligation in carrying out daily life, including in the world of education(Farwati et al., 2021). In this context, the Ministry of Education and Culture (Kemendikbud) has formulated a 21st-century learning paradigm that emphasizes students' ability to seek information from various sources, formulate problems, think analytically, collaborate, and solve problems together (Beniario, 2022). However, in reality, students' Higher Order Thinking Skills (HOTS) are still relatively low, particularly in understanding and applying concepts to solve real-life problems. Therefore, efforts are needed to improve the quality of learning so that students can think critically, creatively, and innovatively. One effective approach to overcome this problem is through the application of the Science, Technology, Engineering, and Mathematics (STEM) learning model. STEM learning integrates scientific and mathematical concepts with technology and engineering processes to train students in problem-solving and developing HOTS (Abdullah et al., 2016).

Efforts to improve the quality of learning require support from various components in education. Teachers, teaching materials, and students are the three basic components in any learning process, and learning models are the elements that integrate all three. According to Joyce and Weil, the teaching model represents a realistic approach to learning, where when teachers help students acquire information, ideas, skills, values, ways of thinking, and ways of expressing themselves, they also teach them how to learn. One of the learning models used to equip students with skills in the 21st-century era is the Science, Technology, Engineering, and Mathematics (STEM) model. In the 2013 curriculum, there is room for teachers to develop learning models that fit their context. In addition, various studies have found that STEM learning models are effective in improving Higher Order Thinking Skills (HOTS), learning outcomes, creativity, student innovation, and other benefits. In line with this view, Febrianti and Widiana, (2021), emphasize that STEAM learning is essential for students to develop a variety of 21st-century skills.

The application of STEM learning models has the potential to assist future generations of students in solving real-world problems through the application of concepts and capacities across disciplines, which encourages critical thinking, collaboration, and creativity (Alatas & Yakin, 2021). In addition, the use of STEAM (Science, Technology, Engineering, Arts, and Mathematics) in learning can also increase creativity, innovation, and ability to solve problems. Research findings also support this, explaining that STEM learning can increase student engagement, creativity, innovation, problem-solving skills, and other cognitive benefits (Pratama et al., n.d.). Furthermore, to implement STEM-based learning, states that it is important to study the curriculum by forming a curriculum development team that can identify basic competencies that can be integrated with STEM content, formulate success indicators, and evaluate the timing of the STEM learning process (Aji, 2020).

Teachers in schools must respond to these curriculum demands by making changes in the learning process that lead to the development of High Order Thinking Skills (HOTS) (Putri et al., 2020). High-level thinking skills, often called advanced thinking skills, refer to the broad use of the mind to meet new challenges. This means thinking at a deeper level than just memorizing facts or telling things to others as we accept them. Hots indicators cover the three highest levels, namely analysis (C4), evaluation (C5), and creation (C6). As stated by Jeong, high-level thinking means thinking at a higher level than simply memorizing a fact or repeating something exactly as it is presented to US (Susanto et al., 2020).

An important factor in implementing this approach is the use of appropriate teaching strategies and the creation of a learning environment that facilitates students' thinking skills. In addition, students' persistence, self-monitoring, as well as an open-minded and flexible attitude also play important roles. According to Newman and Wehlage, when students possess a high level of thinking skills, they can clearly distinguish ideas, argue effectively, solve problems, construct explanations, formulate hypotheses, and understand complex concepts more deeply (Gradini et al., 2022**.** However, the results of preliminary research show that mathematics learning oriented toward Higher Order Thinking Skills (HOTS) in fifth-grade classrooms has not achieved optimal results (Bayasut, 2019). This limitation is caused by the use of learning models that have not sufficiently developed students' abilities to analyze, evaluate, or create. Teachers are still dominant in using lecture methods, memorization of formulas, and simple question-and-answer sessions. Although teachers allow students to discuss, most of the information obtained by students is still delivered directly. Therefore, this study aims to analyze the effect of the Science, Technology, Engineering, and Mathematics (STEM) learning model on improving students' Higher Order Thinking Skills (HOTS) in elementary schools.

In line with this, (Ermawati et al., 2022) emphasising that the use of innovative educational games such as the MAT JOYO (Fun Mathematics Education) application can improve teachers' competence in developing engaging learning media that strengthen students' understanding of mathematical concepts. Furthermore, (Sagita et al., 2023) found that primary school students' problem-solving abilities based on Polya's procedure were still in the moderate category, with students performed well in understanding problems but experienced difficulties in checking their answers. These findings indicate that although several innovations in learning media and problem-solving strategies have been implemented, they have not yet fully addressed the issue of developing students' higher-order thinking abilities. Most of the previous studies have focused on limited aspects such as teacher competence or specific problem-solving steps, without integrating learning approaches that holistically train critical, creative, and analytical thinking. Therefore, this study aims to fill this gap by analyzing the effect of the Science, Technology, Engineering, and Mathematics (STEM) model on students' Higher Order Thinking Skills (HOTS), as well as determining whether there are differences in HOTS between the experimental and control classes (Sidiq et al., 2021), (Sada, 2019).

Methods

This research uses a quantitative approach with quasi-experimental research design (Andromeda et al., 2020). The design used was an unequal pretest-posttest control group design. The study population consisted of fifth graders in 46 elementary schools in Kabupaten

Mejobo. The sampling technique employed was the simple random sampling technique, in which the members of the sample were taken randomly without regard to the strata present in the population. The experimental class consisted of 34 students of Class V SD 5 Jepang and 35 students of Class V SD 1 Kasil. Meanwhile, the control class consisted of 31 students in Class V of SD 2 Jepang.

Pre-experimental data were collected to identify and determine the initial conditions of the three classes that were sampled in the study. The focus of the initial analysis was the fifth-grade students' Higher Order Thinking Skills (HOTS) ability. Pre-experimental activities included interviews and pretests conducted before the implementation of the treatment. Based on the pre-research procedures, the analysis was intended to ensure that the students' initial HOTS abilities in the three groups were relatively equivalent before the research intervention. The results of the Higher Order Thinking Skills (HOTS) pre-experimental data are presented in the following table.

Table 1. The pre-experimental ability of Higher Order Thinking Skill

No	School	Average	Students Completed	Students Not Complete	KKM	%
1	SD 1 Gulang	61,4	11	23	75	32,3%
2	SD 5 Jepang	61,7	11	24	75	31,4%
3	SD 2 Jepang	61,6	10	21	75	32,3%

In table 1. Pre-experimental Higher Order Thinking Skill (HOTS) abilities before the research action from three schools obtained an average percentage of completeness in the poor category. It is shown in the results of the pre-experimental building material at SD 1 Gulang which obtained an average of 61.4 with a classical completeness percentage of 32.3% and 11 students completed and 23 students did not complete the KKM. At SD 5 Jepang, the average Higher Order Thinking Skill (HOTS) was 61.7 with a classical mastery percentage of 31.4%, and 11 students completed and 24 students did not. SD 2 Jepang earned 61.6 with a learning completeness percentage of 32.3% and 10 students completed and 21 did not complete.

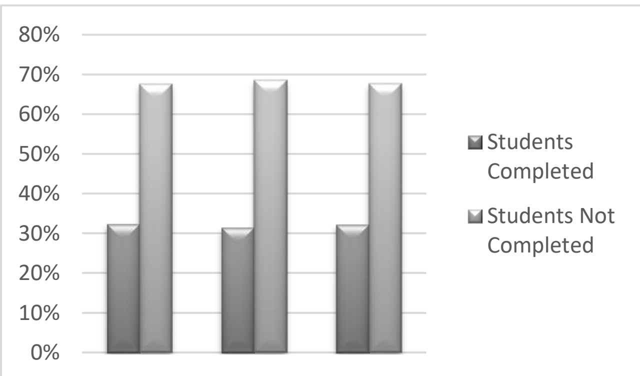

Figure 1. Bar Diagram of Pre-experimental Results of Higher Order Thinking Skill

From the results of the acquisition of classical learning completeness in the pre-experimental implementation of Higher Order Thinking Skill (HOTS) abilities, the application of learning models and media before the research activities in the initial conditions of the three classes has not been effectively used in mathematics learning the material of building cubes and blocks. Learning is done using tools and materials such as cardboard, scissors, ruler knife, and pencil. Cardboard is cut and shaped into a shape called cubes and blocks. Students make cubes starting from the design of the cube image to the precise folding process. After the cubes and blocks are made up of space, then students can learn to calculate the size of the cubes and blocks that have been made respectively.

Result and Discussion

A. Result

The experimental class is an experimental class design designed by researchers to apply treatment using the Science, Technology, Engineering, And Mathematics (STEM) model. The number of subjects used in the study amounted to 35 students of class V SD 5 Jepang. There are two treatments in the research design in the experimental class. The data processing instrument in the experimental class data uses pre-test and post-test data given by the researcher as reference material to assess the Higher Order Thinking Skill (HOTS) ability in the experimental class. Furthermore, the pre-test and post-test data in the study are explained as follows:

Experimental Class Pre-test Data

Pre-test Data in the experimental class provides an overview of the extent to which the ability of Higher Order Thinking Skills (HOTS) before the treatment. This study involved 35 students of Grade V SD 5 ~~Japan~~ as research subjects. Description pre-test data includes the highest value, lowest value, average (mean), standard deviation (standard deviation), and variance.

Table 2. Description of Experimental Class Pretest Data

	N	Minim	Max	Mean	Std. Deviation	Variance
Experiment Class Pretest	35	45	85	64,2	11,1	123,7

Table 2. above describes a statistical description of the pre-test data including the highest score of 85, the lowest score of 45, the mean of 64.2, the standard deviation of 11.1, and the variance of 123.7.

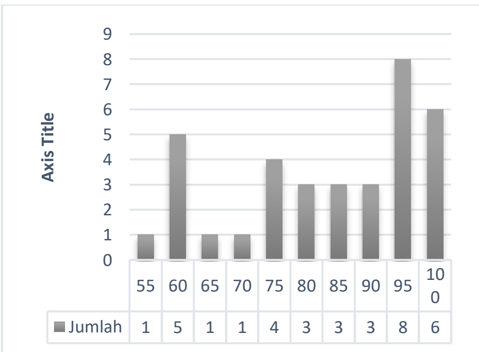

Figure 2. Bar Diagram of Experimental Class Pretest Results

The results of the calculation of the description of the experimental class pre-test data are depicted using the bar chart in Figure 2. above, it is explained that the highest value acquisition is 85 and the lowest value is 45. The value that often appears (mode) in the diagram above is the acquisition value of 60. A total of 35 students scored 45 for as many as 1 student, a score of 50 for as many as 4 students, a score of 55 for as many as 3 students, a score of 60 for as many as 12 students, a score of 65 as many as 4 students, a score of 70 as many as 3 students, a score of 75 as many as 2 students, a score of 80 as many as 2 students, and a score of 85 as many as 4 students.

The results of the calculation of the description of the experimental class pre-test data are depicted using the bar chart in Figure 2. above, it is explained that the highest value acquisition is 85 and the lowest value is 45. The value that often appears (mode) in the diagram above is the acquisition value of 60. A total of 35 students scored 45 for as many as 1 student, a score of 50 for as many as 4 students, a score of 55 for as many as 3 students, a score of 60 for as many as 12 students, a score of 65 as many as 4 students, a score of 70 as many as 3 students, a score of 75 as many as 2 students, a score of 80 as many as 2 students, and a score of 85 as many as 4 students.

Experiment Class Post-test Data

Post-test Data in the experimental class was obtained after the implementation of learning activities involving treatment using Science, Technology, Engineering, and Mathematics (STEM) models. Post-test data description the experimental class includes the highest value, lowest value, average (mean), standard deviation (standard deviation), and variance.

Table 3. Description of Experimental Class Posttest Data

Experiment Class Posttest	N	Minim	Max	Mean	Std. Deviation	Variance
	35	55	100	83,2	14,6	213,1

In table 3. The following is the description of the post-test data for the experimental class consisting of 34 students as research subjects. The results indicate an overall improvement in students' Higher Order Thinking Skills (HOTS) after the implementation of the STEM learning model. The data show that students achieved higher scores and demonstrated more consistent performance compared to the pretest results. This finding suggests that the application of the STEM approach had a positive impact on enhancing students' ability to think critically, creatively, and analytically.

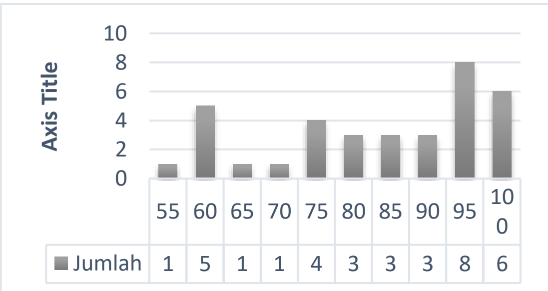

Figure 3. Bar Diagram of Experimental Class Posttest Results

Based on Figure 3. the results of the experimental class post-test data can be illustrated through a bar graph. In the graph, there is a highest value of 100 and a lowest value of 55. The distribution of experimental class post-test data showed that there were 1 student with a score of 55, 5 students with a score of 60, 1 student with a score of 65, 1 student with a score of 70, 4 students with a score of 75, 3 students with a score of 80, 3 students with a score of 85, 3 students with a score of 90, 8 students with a score of 95, and 6 students with a score of 100. Mode experimental class post-test value is obtained at a value of 95.

Control Class Pre-test Data

Pre-test data is research data given by researchers before the action in experimental research. The number of subjects who were processed on the pre-test data was 31 students. The description of the experimental class pre-test data is explained in the table as follows:

Table 4. Description of Control Class Pre-test Data

Control Class	N	Minim	Max	Mean	Std. Deviation	Variance
Pretest	31	40	85	63,3	10,2	105,6

Based on the distribution data in table 4. the description of the pre-test data for the control class explains that the lowest score is 40, the highest score is 85, the mean is 63.3, the standard deviation is 10.2, and the variance is 105.645.

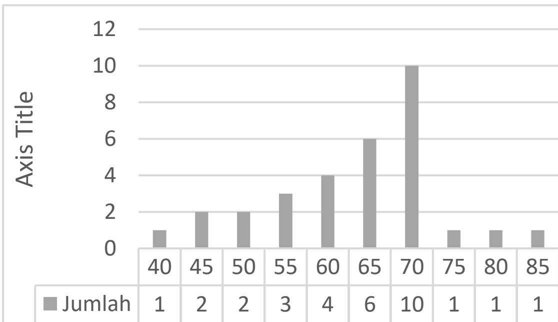

Figure 4. Bar Diagram of Control Class Pretest Results

Based on Figure 4. In the bar graph of the pre-test control class results, there were 31 students who received the following scores: 1 student with a score of 40, 2 students with a score of 45, 2 students with a score of 50, 3 students with a score of 55, 4 students with a score of 60, 6 students with a score of 65, 10 students with a score of 70, 1 student with a score of 75, 1 student with a score of 80, and 1 student with a score of 85. The highest score obtained from the pre-test data was 85, while the lowest score was 40. The grade (mode) that appears most often is 70, with as many as 10 students.

Control Class Post-test Data

Post-test data is data given by researchers after treatment in the experimental and control classes. The number of subjects used in the study on the control class post-test data amounted to 31 students.

Table 5. Description of Control Class Post-test Data

Control Class	N	Minim	Max	Mean	Std. Deviation	Variance
Posttest	31	55	100	77,1	10,8	117,9

Based on table 5. above, it is explained that the post-test data acquisition for the control class of 31 students obtained an average (mean) of 77.1, the highest score of 100, the lowest score of 55, the standard deviation of 10.8 and the variance is 117.9.

Experiment Class Data Results with Control Class

After the data has been processed, it is compared to see the acquisition of the highest score, the lowest score, the mean (mean), variance, the average N-gain score, and the standard deviation (standard deviation) on the pretest and posttest scores for the control and experimental classes.

Table 6. Comparison of Higher Order Thinking Skill (HOTS) Statistics

No	Data	Control		Experimental	
		Pre-test	Post-test	Pre-test	Post-test
	Total Students	31	31	35	35
1	Highest score	85	100	85	100
2	Lowest score	40	55	45	55
3	Average	63,3	77,1	64,2	83,2
4	Standard Deviation	10,2	10,8	11,1	14,6
5	Variation	105,6	117,9	123,7	213,1
6	Percent (%)	38,3%		58,9%	
7	Categories	(Not Effective)		(Sufficiently Effective)	

According to table 6. The results of the comparison of pre-test and post-test values in each class, can be seen the comparison of statistical test results of Higher Order Thinking Skills (HOTS) for building materials cubes and cubes between experimental and control classes. In the control class, there were 31 students with the highest pre-test score of 85 and the lowest score of 40. After the post-test, the control class increased, with the highest score of 100 and the lowest score of 55. The highest pre-test score obtained is 85 and the lowest score is 45 in the experimental class. After going through the post-test, the experimental class also increased, with the highest score of 100 and the lowest score of 55. This shows that the experimental class experienced an increase in results from pre-test to post-test, which can be seen from the comparison of the highest and lowest values increased.

Hypothesis testing

The hypothesis test contains the results of the influence of the Science, Technology, Engineering, And Mathematics (STEM) model on the Higher Order Thinking Skill (HOTS) of Grade V Elementary School Students. Hypothesis testing using the Independent Sample Test test on the posttest value. The decision-making criteria in hypothesis testing are obtained if count > table then Ha = accepted while count < t table then Ho = rejected. The following describes the results of hypothesis testing data in the following research table.

Table 7. Group Statistics

Group Statistics					
	Group	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
HOTS	Experimental	35	83.3	14.6	2.5
	Control Class	31	77.1	10.8	1.9

Table 8. Hypothesis Testing
Independent Samples Test

		Levene's Test		**t-test for Equality of Means**						
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
									Lower	**Upper**
HOTS	**Equal variances assumed**	.82	.019	2.933	64	.036	6.189	3.202	-.207	12.585
	Equal variances not assumed			2.967	62.228	.035	6.189	3.146	-.099	12.477

The results of the statistical group test explained that the average post-test score for the experimental class II was 83.3 and the control class was 77.1 with a total N of 66. The results of the independent sample test in Table 4.18 with equal variance assumed obtained a t-count of 2.9 with the number of degrees of freedom (df) being 64, obtained from the number of samples minus two. The level of significance (sig. 2-tailed) was 0.03 with a mean difference of 6.1.

B. Discussion

Based on the results of the t-test in the table with equal variances assumed, the obtained t-count value (2.933) was greater than the t-table value (2.000). Therefore, the alternative hypothesis (Ha) is accepted. This shows that there is a significant difference between the use of Science, Technology, Engineering, and Mathematics (STEM) learning models and the use of direct learning in improving the ability of Higher Order Thinking Skills (HOTS). Theoretically, this occurs because STEM learning emphasizes an inquiry-based and problem-solving process that integrates multiple disciplines, allowing students to actively construct knowledge rather than passively receive information. The hands-on and contextual nature of STEM activities engages students in analyzing problems, evaluating evidence, and creating innovative solutions, which directly stimulates the higher-order cognitive processes defined in Bloom's taxonomy. The use of STEM learning models has been shown to provide a higher increase in the ability of Higher Order Thinking Skills (HOTS) compared to the use of direct learning. This shows that the STEM learning model, which integrates science, technology, engineering, and mathematics, has a positive impact in developing students' high-level thinking skills. It can be concluded that the use of Science, Technology, Engineering, and Mathematics (STEM) learning models significantly affects the Higher Order Thinking Skills (HOTS) of fifth-grade elementary school students. These results demonstrate the importance of implementing learning models that encourage critical, analytical, collaborative, and creative thinking in an effort to improve students' ability to solve real-world problems (Nasrah, 2021), (Mu'minah, 2021).

Conclusions

The findings of this study indicate that the application of the Science, Technology, Engineering, and Mathematics (STEM) learning model has a significant effect on the Higher Order Thinking Skills (HOTS) of fifth-grade elementary school students. The results of statistical analysis show that the calculated *t*-value (2.9) is greater than the critical *t*-table value (2.0), with a significance level below 0.05, which means that the alternative hypothesis (Ha) is accepted. Furthermore, there was an increase in the average score of students' HOTS from 64.29 before the treatment to 83.29 after the treatment. The N-gain percentage of 58.96 falls into the "quite effective" category, indicating that STEM-based learning contributes positively to the development of students' analytical, critical, and creative thinking skills.

Based on these findings, it can be concluded that the STEM learning model effectively enhances students' ability to think at higher cognitive levels through an integrated approach that connects science, technology, engineering, and mathematics in real-world contexts. Therefore, it is recommended that teachers and schools apply the STEM learning model more broadly to foster students' problem-solving skills and 21st-century competencies. Future research may further explore the long-term effects of STEM learning and its implementation in different subjects and educational levels to optimize its benefits in improving learning outcomes and higher-order thinking skills.

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