Active Learning Using The STEM Approach Improves Critical Thinking Skills Of Elementary School Students

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Abstract. Students are facing challenges in an era where they are required to master science, technology and engineering. The industrial revolution 4.0 demands critical thinking patterns in being competent and absorbing information. The reality that occurs in elementary schools shows that thematic learning lack of develop critical thinking skills. The purpose of this study was to find out (1) how the application of STEM (Science, Technology, Engineering and Mathematics) learning to the critical thinking skills of elementary school students; (2) measuring the increase in students' critical thinking skills after learning by using the STEM approach. The research is a quasi-experimental (quasi-experimental) design. This research was conducted at SDN Cipagalo 01, Bandung Regency. Data obtained from test and non-test data. This study uses data collection techniques in the form of multiple choice critical thinking test questions. While the non-test used student worksheets and observation sheets. The results showed that the application of active learning using the STEM approach to improve critical thinking skills of elementary school students in science subjects was quite effective. Analysis of paired sample t-test shows the value of sig. (2-tailed) of 0.000 < 0.005, which means that there is an increase in students' critical thinking skills.

Keywords: STEM, active learning, elementary school, critical thinking, thematic

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INTRODUCTION

The current education system focuses on 21st century learning (Ardianti et al., 2019). Educators and students are required to follow these developments. One of the new breakthroughs in 21st century learning that can be used to solve everyday life problems is the Science, Technology, Engineering, and Mathematics approach or abbreviated as STEM (Sumaya, et al., 2021; Lidinillah, et al., 2019). The application of STEM learning can help improve students' critical thinking skills (Davidi, et al., 2019; Adiwiguna, et al., 2019; Akhmad, et al., 2020).

These critical thinking skills really need to be developed from an early age so that students are able to face increasingly complex future challenges. Critical thinking skills do not appear suddenly, but this ability must be trained in every lesson. The problem currently faced is that students' critical thinking skills at the elementary school level have not been handled systematically so that students' critical thinking skills are still low (Akhmad, et al., 2020). Windayana (2007) shows that the critical thinking skills of elementary school students are still low. This is indicated by the average initial test score of students who only obtained 5.80, meaning that this average indicates the low ability of students to think critically mathematically. According to Glaser (in Fisher, 2009, p. 7), that in critical thinking there are several abilities including: a) recognizing problems, b) finding ways that can be used to deal with problems, and c) gathering and compiling the necessary information. Other indicators that can be measured on critical thinking skills are explained by several other experts, but in this study the critical thinking skills used refer to the opinion of Facione (2013), which explains that critical thinking skills consist of 6, namely: interpretation, analysis, conclusion , evaluation, explanation and self-regulation. Each of these critical thinking skills also has sub-skills and questions that will lead individuals to have critical thinking skills.

Learning critical or creative thinking skills can be done in elementary schools using the Integrated Thematic Instruction (ITI) model. This learning is different from the thematic approach as a basic reference for learning materials and activities, where themes connect both certain subjects and between subjects. This thematic learning has been scientifically proven to be successful in boosting students' memory (Fakhriyah et al., 2016).

The 21st century learning paradigm emphasizes students' abilities to think critically, be able to connect knowledge with the real world, master information and communication technology, and collaborate (Janah et al., 2019). The STEM approach is a very appropriate approach to use in 21st century learning (Sumaya, et al., 2021). STEM is a learning subject that is popular all over the world, which is effective in implementing integrated thematic learning because it combines the four main fields of education namely science, technology, mathematics, and engineering. Torlakson (2014) states that the approach of these four perspectives is a harmonious match between problems encountered in the real world and also problem-based learning. This approach is able to create an integrated learning system and active learning, because these four aspects are needed simultaneously to solve problems. This means that with the STEM approach, students do not only remember concepts, but rather how students understand and understand scientific concepts and how they relate to everyday life. Learning through the STEM approach has proven effective in increasing students' critical thinking.

Active learning is a student-centered learning strategy and is effective in increasing the mastery of concepts scores (Freeman et al., 2014). Educational research has shown that compared to teacher-centered learning, learner-centred learning methods lead to improved learning outcomes, improved critical thinking skills, and improved memory in the fields of science, technology, engineering, and mathematics (Felder, 2016) . The results of the TIMSS (Trends in International Mathematics and Science Study) and PISA (Program for International Student Assessment) studies show that Indonesian students' thinking skills are still low, especially in science. Students do not yet have the skills to become problem solvers (Pertiwi, 2017). Active learning using the STEM approach applied in this study is learning that emphasizes the STEM approach carried out face-to-face.

Based on the background as mentioned above, this study aims to see how the application of STEM-based active learning to simple machine subject and whether the application of the STEM approach affects the acquisition of critical thinking skills in elementary school students. There are many learning methods and approaches that can improve students' critical thinking skills, but the author is interested in using the STEM approach because according to Sumaya's research, et al. (2021) that the learning outcomes of grade IV elementary school students, increasing in energy material and its changes and integrating STEM learning into the elementary school curriculum in Indonesia are very appropriate to apply to support the development of 21st century skills of elementary school students (Lidinillah, et al., 2019) . The STEM approach with the project-based learning model is more effective in improving the critical thinking skills of grade IV students in science learning content (Dywan, 2020). This research is expected to provide benefits, namely as the first experience of seeking knowledge in active learning using a STEM-based learning approach.

METHOD

This research is a quantitative study using a one-group-pretest-posttest design. The design used does not have a control group to be compared with the experimental group (Creswell, 2014). The pretest and posttest results were compared in the experimental group. The model used can be seen in **Table 1.**

Tabel 1. *One Group Pretest Posttest Design.*

Pre Test	Treatment	Post Test
O	X	O

Information
O : Initial test (pretest) before the treatment is given
O : Final test (posttest) after the treatment is given
X: Treatment (treatment) to the experimental group, namely by using a problem-based learning model.

In this study the data collection technique used was a descriptive test that measures the critical thinking skills of elementary school students. Through a descriptive test, open-ended respondents' answers were presented and the critical thinking level of the samples examined was analyzed. The test questions were submitted to the sample at the beginning and after the treatment the results were analyzed. To see the sample's response to problem-based question, questionnaires were distributed and used as supporting information for discussion. Qualified experts evaluate the content validity of the instrument used, and after validation, the instrument is tested on out-of-sample V grade students to determine the validity, reliability, strength, and difficulty index of the instrument. Critical thinking indicators used for this study can be seen in **Table 2.**

Table 2. Critical Thinking Indicators of The Study

No.	Skills	Sub-skills
1	Interpretation	Classifying Encode meaning
2	Analysis	Analyze arguments Recognize reasons and arguments
3	Explanation	Declare results
4	Evaluation	Access the credibility of the statement

Source: Facione, 2013

RESULTS

Before conducting the research, the validity and reliability of the instruments used in the research were first tested. Validity test is used to determine whether the instrument used is feasible or not. The reliability test determines whether the instrument is consistent when the questions are reused. Hardware testing is carried out outside the research sample. The instrument to be tested is a critical thinking tool.

1. Description of the Application of Learning Using the STEM Approach

The STEM approach is used to improve the critical thinking skills of class V students at SDN 01 Cipagalo Bandung in 3 meetings in class. The first meeting conducted a pretest or test of students' initial knowledge**.**

After the pretest was carried out, the teacher through an active learning strategy carried out 6 learning phases as follows:
The teacher does the introduction for about 10 minutes.
Phase 1, the teacher motivates students by inviting discussion by asking questions.
Phase 2, the teacher provides information about the volume of cubes and blocks.
Phase 3, Students work on Student Worksheet 1 about cubes and blocks.
Then students in groups were asked to find information on the internet about how to make cubes.
Phase 4, the teacher evaluates the group when they are discussing. When assessing, the teacher uses a rubric. Students who have not been assessed on this occasion can be assessed when they have discussions on other occasions.
Phase 5, The results of student discussions are discussed classically and concluded together.
Each group was then asked to make a regular polygon (rectangle) into a 3-dimensional shape (cube) from the paper provided.

Phase 6, The group that succeeds in making the cube correctly is given an additional value (reward).

At the second meeting, the introduction was conducted for approximately 10 minutes.
Phase 1, the teacher reviews the previous material by asking questions
and motivate students.
Phase 2, Students get an explanation of the relationship between style and
motion in everyday life and get explanations about
simple machine.
Phase 3, students observe objects brought by the teacher in the form
simple machine. Students in groups are asked to work on Student worksheets on simple machines.
Phase 4, the teacher supervises the discussion and assesses students.
The teacher also ensures that students are polite, speak politely, and
respect each other during group discussions. Participants were asked to return
to their respective seats to get briefed on the next task. The teacher asks an open question: "what have you learnt?", "What material do you not understand yet?".
Students are asked to return to groups.
Students are given questions in the form of cases.
In groups students are asked to design tools to find solutions
on the problem in a given case (experimental)
Students are given tools and materials in the form of ice cream sticks and rubber bands to make tools (products).
Phase 5, After it is made, students in groups try out the tools that are made
in front of the class.
Phase 6, Groups that can solve problems according to the specified criteria
awarded the highest points.

2. Instrument Test Result Data

a. Instrument Validity Test

The test of critical thinking skills in science lessons on the subject of simple machines tested consisted of 8 questions. Of the 8 questions, 2 items were considered invalid. The correlation data is as in the following table3.

Table 3. Interpretation of the Correlation Coefficient

Correlation between	Nilai Korelasi (Pearson Corellation)	Probabilitas Korelasi [sig.(2-tailed)]	Conclusion
Item No. 1 with Total	0,839	0,000	Validitas Baik
Item No. 2 with Total	0,507	0,022	Validitas cukup
Item No. 3 with Total	0,593	0,006	Validitas Cukup
Item No. 4 with Total	0,763	0,000	Validitas Baik
Item No. 5 with Total	0,819	0,000	Validitas Baik
Item No. 6 with Total	0,645	0,002	Validitas Cukup

Based on **Table 1.3**. above, according to the criteria, all instrument items are declared valid, because the correlation probability value [sig. (2-tailed)] < from a significant level (α) of 0.05. In addition, according to the test instrument validator, it states that the critical thinking ability test instrument can be used for research because it meets all valid criteria.

Analysis of the validity of critical thinking questions with Excel. The test instrument consisted of two critical descriptive questions. For N = 20 and α= 0.05, the r table is 0.44. For critical thinking data, the Pearson correlation values are 0.86 and 0.74. All items have Pearson correlation > 0.44, so all items are valid. Analisis validitas soal berpikir kritis dengan Excel. Instrumen soal yang diujikan terdiri dari dua soal deskriptif kritis. Untuk N = 20 dan □ = 0,05 maka r tabelnya adalah 0,44. Untuk data berpikir kritis, nilai korelasi Pearson adalah 0,86 dan 0,74. Semua item memiliki korelasi Pearson > 0,44, sehingga semua item valid.

b. Reliability Test

The instrument reliability test was conducted on 20 students with a total of two critical questions. On the results of the reliability of critical thinking instruments, Cronbach's alpha for critical thinking skills is 0.50 which means that critical thinking instruments are reliable.

3. Research Result Data

Based on the calculation results of the Shapiro-Wilk correlation for the pretest and posttest, the sig. respectively 0.195 and 0.120. The significance value is greater than 0.05, then Ho is accepted. It is concluded that the pretest and posttest data come from populations with normal distribution.

Analysis of paired sample t-test is a method of testing the hypothesis with the data used is not independent (paired). The paired characteristics include the research sample carried out by two different treatments, namely before and after the use of a learning approach using STEM to measure the increase in critical thinking skills. The statistical hypothesis used is as follows.

Ho : μ_1 = μ_2 : There is no increase in critical thinking skills.

Hi : μ_1 ≠ μ_2 : There is an increase in critical thinking skills.

If, sig < 0.025 then Ho is rejected, while sig > 0.025 then Ho is accepted. From the results of the analysis of sig. (2-tailed) of 0.000 <0.025, meaning that Ho is rejected, it is concluded that there is an increase in critical thinking skills.

DISCUSSION

Based on the results of the analysis it is known that the significance price meets the requirements for a sign <α = 0.05, which means that there is an effect on increasing critical thinking skills after being given treatment.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Pre test - Post test	-10,33333	13,76736	2,51356	-15,47415	-5,19252	-4,111	29	,000

Figure 1. The results of the Paired Sample t-Test

A factor that might have contributed to better results from pretests was student-centered learning. Students are invited to be active in learning. Student-centered classes seem to create conditions that can develop critical thinking skills. This finding corroborates other studies that

use the STEM approach in learning to improve students' critical thinking skills (Khoiriyah, 2018; Lestari, 2016).

The average pretest and posttest acquisition of students' critical thinking skills can be seen in **Table 4**.

Table 4. Average Pretest and Posttest Students' Critical Thinking Skills Acquisition

No.	Indicator/Sub-indicator Critical Thinking Skills	Nilai	
		Pretest	Post-test
1.	Interpretation		
	- Classifying	40	60
	- Encode meaning	40	50
2.	Analysis		
	- Analyze arguments	30	55
	- Recognize reasons and arguments	40	60
3.	Explanation	55	75
4.	Evaluation	50	70

Based on **Table 1.4** it is known that the average score of acquiring critical thinking skills after being treated has increased. These results indicate that learning using the STEM approach is quite beneficial for improving students' critical thinking skills. According to Suryani (2012) what can train students' skills in asking and answering questions is that there are clear problems to solve, looking for data or information to solve problems, establishing temporary answers, testing the correctness of temporary answers and drawing conclusions.

According to Ersoy (2015), understanding the problem is the first and basic stage of problem solving. Students who understand the problem well will reach a solution and choose the appropriate strategy. The existence of a stage of presenting facts to find solutions can train students to improve their affective abilities in asking questions from the facts that have been presented. At this stage students also design experiments to find solutions to the problems given. The experimental design to solve the problem is in the form of making tools in the form of simple planes from only two types of tools, namely sticks and rubber. Students are actively directed to develop their critical thinking skills through practical activities and direct observation.

The increase in students' critical thinking skills on indicators of giving conclusions is possible for several reasons: (1) the level of difficulty of the questions used is at easy and medium levels; (2) the questions given are in the form of multiple choices accompanied by pictures or initial information so that it allows students to develop more ideas in finding solutions to problems.

Students' critical thinking skills are not maximized because they do not get the opportunity or even never practice these abilities because the learning process is short and monotonous. Anggraeni et al, 2013 (in Prihartiningsih, 2016) states that to develop students' critical thinking skills can be done by asking questions and questioning the phenomena being studied. Educators must be able to create fun learning and encourage students to be active in learning activities. Intensive interaction between students through group work, teachers and learning materials is expected to provide opportunities for students' thinking skills. Therefore, to obtain maximum results it takes quite a long time to train students' critical thinking skills.

Student Questionnaire Results

In addition to observing learning outcomes, researchers distributed questionnaires to find out students' responses to learning through STEM. Based on the survey given to students, the following description is obtained. From the results of the student survey responses, it can be illustrated that out of a total of 30 grade V students, as many as 17 people strongly agree (SS) that learning through the STEM approach provides space for students to think while solving a problem, while there are 8 who agree (S) person. The same students strongly agree that the STEM

approach makes learning more interesting. As many as 18 students stated that they strongly agreed that designing tools could train skills, while 8 students agreed. From the description of the data, it can be concluded that more than 80% of students find learning with the STEM approach interesting and provides space for reflection when solving problems.

Information about students' responses to learning using the STEM approach was obtained from student questionnaires and informal interviews. The questionnaire contains positive and negative questions. The questionnaire used and its processing can be seen in the following table.

Table 5. Results of Analysis of Student Responses to STEM Learning.

No.	Statement	SS	S	RR	TS	STS
1	With the STEM approach I can provide a simple explanation of the use of simple machines in everyday life	12	12	4	2	0
2	The STEM approach trained me to be able to answer the questions discussed in the Student Worksheet (LKPD) about the types of levers	14	12	2	1	1
3	The STEM approach gives me space to think about solving a problem	17	8	3	0	2
4	The STEM approach makes thematic learning more interesting	17	10	2	0	1
5	In my opinion, the STEM approach is not useful because it does not explain the material being discussed	1	1	5	7	16
6	I think designing a tool is able to train skills	18	8	2	2	0
7	The approach used by the teacher made me confused to understand the material being taught	2	5	3	11	9
8	I have difficulty distinguishing and giving examples of the types of levers in everyday life	2	5	9	7	6
9	I don't like it when teachers carry out thematic learning using the STEM approach because it's not useful in everyday life	0	0	5	9	16
10	With the STEM approach I can't get involved in solving the problem	2	2	5	7	14

Keterangan: SS= Sangat Setuju, S= Setuju, R= Ragu, TS= Tidak Setuju, STS= Sangat Tidak Setuju

CONCLUSION

Based on the results of the research and data analysis that has been carried out regarding efforts to apply the STEM approach, it is concluded that the application of learning using the STEM approach to improve the critical thinking skills of elementary school students in science subjects is quite effective. There is an increase in the critical thinking skills of elementary school students in science subjects through learning using the STEM approach, although not too significant.

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