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PROMOTING STUDENTS' CRITICAL THINKING SKILL THROUGH STEM-BASED LEARNING ON TRIGONOMETRY

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Abstract

Critical thinking skills must be applied and developed in the curriculum and learning process to support students' high level of thinking ability. However, some learning processes in Indonesia do not support critical thinking ability. Some studies revealed that STEM-based learning can empower students' ability to develop students' 21st skills. Thus, this study aims figure out whether STEM-based learning can support students' critical thinking skills of trigonometry. This study was an experimental study conducted on 10th grade students of social studies MAN 1 Cirebon. The data were collected by using tests. The result showed that there was an improvement of students' critical thinking skills after the implementation of STEM-based learning on trigonometry. Students' posttest score of 79.83 was greater than the pretest score, which was 30.81. The paired sample t-test analysis showed that there was a significant increase from pretest to posttest score. Moreover, there was an improvement of students' critical thinking indicators before and after the implementation of STEM-based learning, namely the ability of analyzing, synthesizing, solving, concluding, and evaluating. Thus, it can be concluded that there STEM-based learning can be applied to promote students' critical thinking skills.

Keywords: STEM, critical thinking, trigonometry

INTRODUCTION

The 21st century students need to prepare themselves in facing globalization. Octaviyani, Kusumah, Hasanah (2020) points that 21st century skills include creative thinking, critical thinking, collaborative skill, and communicative skill (also known as 4Cs). In educational aspect, the learning process should facilitate the necessity of 4C skill so students can encounter the 21st century life.

According to Firdaus, Kailani, Bakar, Bin, & Bakry (2015, p. 220) critical thinking skills must be applied and developed in the curriculum and learning process to support students' high level of thinking ability. The ability to think critically is basically the ability to determine whether information is relevant or irrelevant, and to make decisions about what to do to achieve the goal. Critical thinking emphasizes rational and reflective thinking so that it can support a decision-making process (Ennis, 1996). Angelo (1985) proposed five

indicators of critical thinking skills, namely analyzing, synthesizing, solving problems, concluding, and evaluating. Azizah, Sulianto, & Cintang (2018, p. 64) suggests that critical thinking skills are students' cognitive processes in analyzing and solving a problem with systematic and thorough steps, and classifying information to arrange strategies to solve the problem.

Critical thinking skills play a significant role on students' success in learning. According to Akdemir & Yavuz (2018), critical thinking skills contribute to the accomplishment of other mathematical skills. However, some learning processes in Indonesia do not support critical thinking ability. Some studies (such as Retnowati, Riyadi, Subanti, 2020; Ariyatun & Octavianelis, 2020) describe that mathematics learning methods applied in Indonesia are generally conventional and teacher-centered. Students are passive during the learning process thus students' involvement in the learning process tends to be low. The learning process becomes tedious as the students only listen the teacher's explanation without doing any interesting activities in the classroom such as hands-on activities (Astuti, Toto, &Yulisma, 2019).

Based on several surveys that have been conducted before, Indonesia always ranks at the bottom. In 2015 the results of TIMSS (*Trend in International Mathematics and Science Study*) indicated that Indonesia's position was in 44th place out of 49 countries with an average score of 397 out of 500 (Hadi & Novaliyosi, 2019). In the results of PISA (*Programme For International Student Assessment*) survey in 2018, Indonesia was in 64th position out of 79 countries in science and mathematics (OECD, 2019). In addition, as mentioned by Saputri, Sajidan, Rinanto, Afandi, & Prasetyanti (2019), some studies proved that the cases of low students' critical thinking research was found in many areas in Indonesia. The results of these surveys and studies are evidence that students' critical thinking skills in Indonesia need attentions.

Many studies revealed that students consider Trigonometry as a difficult subject (Safitri, 2017; Usman & Muhammed, 2017; Nanmumpuni & Retnawati, 2021). The study of Usman & Muhammed (2017) showed that students put more effort in solving Trigonometry Diagnostic Test (TDT). Many students merely rely on formulas given by the teacher without building a deep understanding on trigonometry (Nanmumpuni & Retnawati, 2021).

Science, Technology, Engineering, and Mathematics (STEM) is disciplines that can be correlated to each other. Sa'ida (2021, p. 124) suggests that STEM learning is included as a contextual learning in which students use their environments in learning. STEM-based learning is applied in an integrated way to develop products, processes, and systems that are advantageous in everyday life. STEM learning is also in line with 21st century learning because it is contextual, so it can empower students' ability to develop their 21st skills (Hernandez in Isdianti, Nasrudin, & Erman, 2021).

STEM-based learning starts with an exploration about the topic. The students investigate about the topic and find the correlation between the topic and other subjects such as science, technology, and engineering. The process of investigation and making connections among STEM subjects can support students' critical thinking. Previous studies on STEM showed that there was an improvement in learning outcomes before and after integrating STEM in the learning activities (Hernandez in Isdianti, Nasrudin, & Erman, 2021; Afifah, Ilmiyati, & Toto, 2019; Sari & Setiawan, 2020). Moreover, Asigigan & Samur (2021), and Rizqiyana, Setyaningsih, & Sari (2021) revealed that STEM practices can support students in developing their critical thinking disposition level. Based on the reasoning above, this study aimed to figure out whether the implementation of STEM-based learning on Trigonometry can improve students' critical thinking.

METHOD

Research Approach

This study was a quantitative research, the type of research that uses statistical procedures or measurement criteria. Quantitative research is usually required to use numbers, both in data collection, data interpretation, and presentation of data analysis (Arikunto, 2013).

This research was an experimental study as it is necessary to conduct an experiment to determine the response of a situation so that its effect can be investigated. This study applied one group pretest-postest design. In this study the researcher used one class, only the experimental class group, intending to compare before and after the treatment (Sugiyono, 2013).

Time and Location

This study was conducted in MAN 1 Cirebon, West Java. This school was chosen as the learning model applied in this school was still conventional and teacher-centered. The study was carried out in about 3 months, starting from February to April 2022.

Population and Sample

The population of this study was 10th grade students of MAN 1 Cirebon. The sample of this study was students of class X IPS 4 MAN Cirebon 1 academic year 2021/2022. In this study, one of the researchers performed as the teacher who implemented STEM-based learning in the class X IPS 4 MAN Cirebon 1.

Research Instruments

Sugiyono (2013, p. 148) states that the research instrument is a tool used to measure the observed variables. The instrument in this study was used to figure out students' critical thinking skills on trigonometry after the implementation of STEM-based learning. The instrument used was a test. The test is useful for measuring students' critical thinking on trigonometry. The test was carried out before the implementation of STEM-based learning or pretest, and after the implementation of STEM-based learning or posttest.

The critical thinking test was in the form of essay questions. The critical thinking test included five indicators of critical thinking skills adopted from Angelo (1985), namely analyzing, synthesizing, solving problems, concluding, and evaluating.

The test has been tested for the level of validity and reliability, the results of all the questions used have been declared valid and have a moderate level of reliability. The result of test item analysis was presented in Tabel 1 below.

Tabel 1 The Result of Test Item Analysis
Reliability = 0,469, Aiken V = 0,983

Test item	Validation		
	r_{hitung}	r_{tabel}	Interpretation
1	0,460	0,349	Valid
2	0,735		Valid
3	0,638		Valid
4	0,638		Valid

Data Analysis

The data was analyzed quantitatively. A paired sample t-test was used to analyze the data. A paired sample t-test is a test to compare the mean of two paired groups, such as pretest and posttest (Ross & Wilson, 2017). The paired sample t-test was carried out by using SPSS with the following hypotheses:

Ho: There is no significant difference between the average score of pretest and posttest

Ha: There is a significant difference between the average score of pretest and posttest

RESULT AND DISCUSSION

Result

Before the application of STEM-PjBL, the students were tested by giving pre-test. Thereafter, STEM-based learning was implemented by one of the researchers who acted as the teacher. In the beginning, the teacher asked students' initial understanding of trigonometry and the application of trigonometry in daily life. Then, the teacher engaged students to find information about tools to measure angles, heights and distances of buildings related to trigonometry. The teacher explained about clinometer briefly and asked students to collect information about clinometer by utilizing internet or other sources. This activity integrates the aspect of *technology* in STEM. After finding the information, the students are divided into 7 groups consisting of 5 students for each group.

Each group discussed the information about clinometer and how to build clinometer. Each group was required to build a clinometer as a project assignment. This activity integrates *engineering* in STEM such as designing clinometer as a tool to measure angles, heights and distances of buildings related to trigonometry. After building a clinometer, they used the clinometer as a tool to solve problems related to trigonometry, namely to measure the angle, height and distance of a building.

Figure 1
Clinometer Props

Figure 2
Application of Clinometer

The solution of the problems was discussed in each group. Thereafter, each group presented the result. In the presentation session, some different results emerged. The different results appeared because an inaccurate measurement and calculation. Those different results were discussed and the students became aware of the cause of different results.

In the end of the last meeting, the post-test were given to the students. The score of pre-test and post-test of the students' critical thinking skills was presented in Table 2 as follows.

Table 21 Score of Critical Thinking Pre-test and Post-test

Class	Number of Students	Score	
		Pretest	Posttest
X IPS 4	35	30,81	79,83

The students' test results on critical thinking ability variables increased in every aspect as shown in Figure 3. This result indicated that the STEM-based learning was able to to support students' critical thinking skills.

Meanwhile, to find out the improvement of students' critical thinking ability, paired sample t-test was carried out.

Table 3 Paired Sample T-Test Result

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Pretest Postest	- 49.200	16.128	2.726	-54.740	-43.660	-18.048	34	.000

Based on the result of paired sample t-test in Table 3, the Sig. value is 0.000 < 0.05. It indicated that there was a significant difference between the average of pretest and the average of posttest. In this case, the average of posttest was significantly higher than the average of pretest. As shown in Table 3, there was a significant increase of students' critical thinking before and after using the STEM-based learning.

The evolvement of each critical thinking indicators can be seen in Figure 3. Based on Figure 3, the average percentages of pretest and posttest students' critical thinking skills in each aspect experienced an increase.

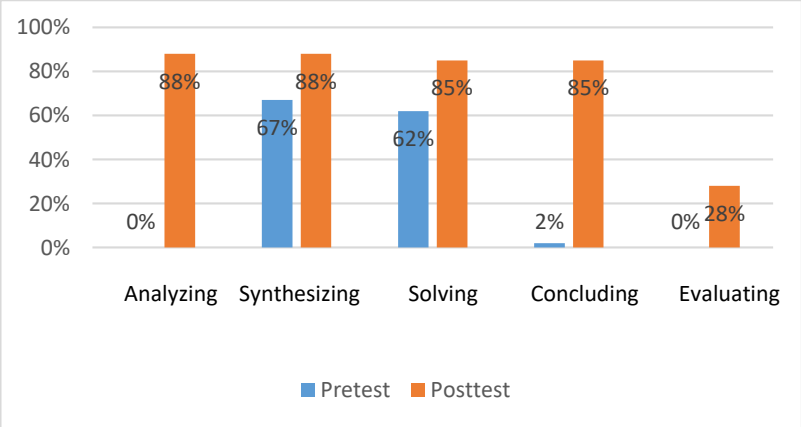

Figure 3 Graph of Critical Thinking Indicators on Pre-test and Post-test

Discussion

In general, students' critical thinking ability increases after the implementation of STEM-based learning. During the learning process, students integrate the aspect of *technology*, *engineering*, and *mathematics* in building clinometer to learn about trigonometry. The STEM approach applied in this study was embedded approach. An embedded STEM means that the dominant knowledge is obtained by stressing the real world situations (ITEEA in Roberts and Cantu, 2012). In this study, the dominant knowledge, mathematics, was taught by embedding the technology and engineering domains.

The test results revealed that there was a significant increase of students' critical thinking after the implementation of STEM-based learning. Before the implementation of STEM-based learning, students' ability of some critical thinking indicators was very low. Specifically, Students did not show their ability in analyzing, concluding, and evaluating. After the implementation of STEM-based learning, the students demonstrated an improvement in those aspects.

In the aspect of analyzing, students were asked to find important information contained in the problem to solve the problem. After applying the STEM-based learning, the aspect of analyzing increased because students could answer the questions by conducting an analysis such as sketching the model of the problem as shown in Figure 4. Furthermore, students apply the concept and carry out the calculation process correctly.

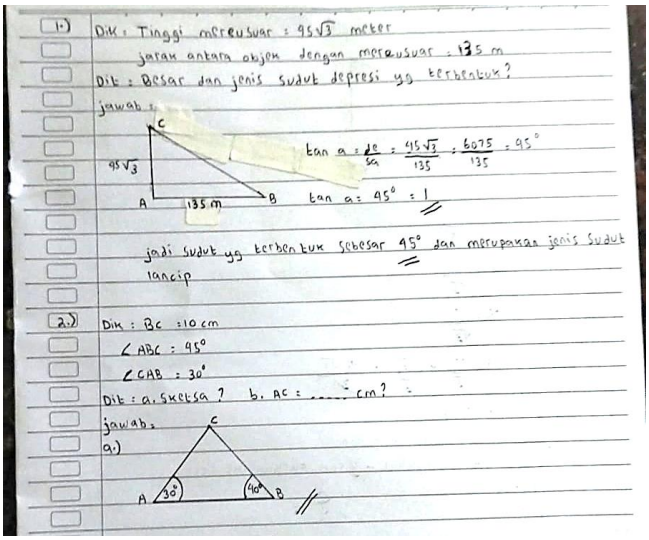

Figure 4 *Posttest* Results number 1 and 2

Furthermore, in the aspect of concluding, students were asked to write down the conclusions based on the calculation result. Based on figure 4 below, the student was able to understand and rewrite information contained in the questions. The student also carried out the synthesis process by applying the appropriate concepts or formulas which is tangent comparisons. Then, the student carried out a systematic calculation process to find out the distance of an object to another object. Furthermore, the student wrote down the conclusion by bringing back the result to the context of the problem.

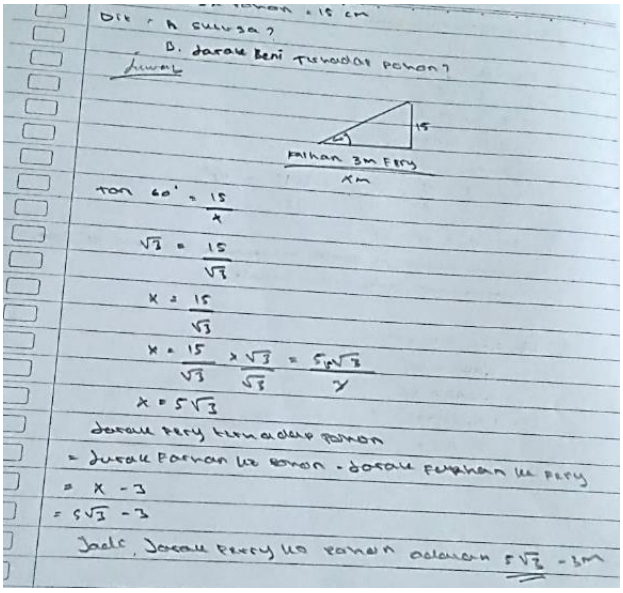

Figure 5 Student *Posttest* Results number 3

The result of this study was supported by other related studies. Previous studies investigating the impact of STEM integration in the learning process revealed that integrating STEM in the learning process contributed positive effects on the development of students' critical thinking skills (Utami, Vitasari, Langitasari, & Muliyati, 2021; Mater et. Al., 2020; Isdianti, Nasrudin, & Erman, 2021; Hacioglu & Gulhan, 2021; Onsee & Naungchalerm, 2019). Based on the discussion of the results of the study, it can be concluded that the application of the STEM-based learning model can improve students' critical thinking skills.

CONCLUSION

Based on the results of this study, it can be concluded that the application of the STEM-based learning model can support students' critical thinking skills in general and in each indicator of critical thinking. This was shown by the result of paired sample t-test which indicated that there was a significant increase of students' critical thinking on trigonometry before and after the implementation of STEM-based learning. Moreover, there was an improvement of students' critical thinking indicators before and after the implementation of STEM-based learning, namely the ability of analyzing, synthesizing, solving, concluding, and evaluating.

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