Asia-Pacific Forum on Science Learning and Teaching

亞太科學教育論壇

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E-mail: apfslt@sci.ied.edu.hk Website: http://www.ied.edu.hk/apfslt

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1. **Submission.** Articles should be sent to the Chief Editor, APFSLT Editorial Board (c/o Science and Environmental Studies Department, The Education University of Hong Kong, 10 Lo Ping Road, Tai Po, HONG KONG, CHINA; Phone: 852-29487650; Fax: 852-29487676, Email: apfslt@eduhk.hk) in MS-Word format by (a) post, (b) email (for file size less than 5 MB) or (c) online submission at http://has.eduhk.hk/apfslt/.

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REFEREE COMMENT 2

The implementation of the STEM approach in learning to the critical thinking skills of fifth-grade elementary school students in Lampung Province

Comment [A1]: The title of paper typing in sentence case, without Acronym or abbreviation

Nelly ASTUTI[1], Riswandi[2], Ujang EFENDI[3] and Nur Ridha UTAMI[4]

Elementary School Teacher Education, Faculty of Teacher Training and Education, University of Lampung, INDONESIA

Corresponding Author's E-mail:nelly.astuti@fkip.unila.ac.id

Abstract

Critical thinking skills is an important aspect of the learning process in the 21st century era. It can be improved with the Science, Technology, Engineering, and Mathematics (STEM) approach in learning. The purpose of this study is to analyze the implementation of the STEM approach in learning to the critical thinking skills of fifth-grade elementary school students in the province of Lampung. The benefits of this research are (1) being able to improve students' critical thinking skills through the STEM approach, (2) the integration of the four aspects of the STEM approach can create active, innovative, and logical thinking students, (3) as a renewal and innovation in learning so that learning is oriented to students, and (4) the STEM approach can be used as an input for learning in primary school. This study uses a quasi-experimental design with experimental and non-experimental classes. The population of this study amounted to 59 students and the research sample amounted to 29 students. The data was obtained using a test in the form of an essay which consist of 6 questions. Items measure critical thinking skills with six indicators, namely focus, reason, inference, situation, clarity, and overview. The reliability of the items in the high category

Comment [A2]: This number of students can be used as a sample

Comment [A3]: the sample used is not representative

(0.65) and the validity of the items in the moderate to very high category (0.44-0.95). The difference in the test results of the experimental class is 68.695 and the non-experimental class is 61.250. Data analysis using Kolmogorov Smirnov with the largest|FT-FS|t-test < table value of 0.111< 0.246. The results showed that the critical thinking ability was significantly higher in the experimental class students than in the non-experimental class. In conclusion, the results of the research on the critical thinking skills of fifth-grade elementary school students in Lampung Province were influenced by the STEM approach with a significance level of 0.111 (sig <5%). The implementation of the STEM approach in learning plays an important role in improving the critical thinking skills of fifth-grade students.

Keywords: critical thinking skills, STEM approach.

Introduction

21st century skills in the world of education are skills that must be mastered by every student and even become essential to the progress of education in Indonesia. These skills are being able to think critically and problem-solving, learning and innovating skills, collaboration, communicating effectively, analyzing information, and having life skills (Wijaya et al., 2016; Zubaidah, 2016). Various skills are pursued by all elements of education so that students can compete with other countries and are ready to face life's challenges (Astutik & Hariyati, 2021; Nuryanti et al., 2018). Students in primary schools need to be supported to have a 21st century skills such as critical thinking skills.

Critical thinking skills play an important role in today's life aspects (Erikson & Erikson, 2019; Halpern, 2014; Prajapati et al., 2017). Every problem that students encounter will be easily overcome if they can think critically. Critical thinking ability is a person's ability to think that is fundamental, reasonable, and reflective which includes activities to analyze, synthesize, create, identify questions, and be able to make logical conclusions and characterize 21st century learning (Asyari et al., 2016; Ennis, 2011; Mahanal et al., 2019; Mardliyah, 2019; Schmaltz et al., 2017). Critical thinking skills are also part of the mental process that teaches how to understand events and environmental conditions (Zubaidah et al., 2018). Someone who can think critically will look different as if he has high curiosity. Changwong et al. (2018) and Cintamulya (2019) state the importance of critical thinking skills, which are needed to help students conceptualize themselves to be active, skilled, find problems, collect data, make hypotheses, and apply all positive things learned.

Comment [A4]: The use of words must pay attention to consistency

Comment [A5]: The use of words must pay attention to consistency

Critical thinking skills not only transfer knowledge from one domain to another but educators teach how these abilities can develop efficiently and contribute in every field (Zohar et al., 1994). The effectiveness of a person's critical thinking ability needs an indicator to determine the achievement of a predetermined target. Ennis (2011) revealed that there are six indicators of critical thinking skills called Focus, Reason, Inference, Situation, Clarity, Overview (FRISCO). The six indicators of critical thinking skills provide a broad and useful range of knowledge for students. So, by the six indicators it is hoped that they can be a reference in measuring students' critical thinking skills.

In fact, the conditions that occur in elementary schools today are the low critical thinking skills of students. This problem is because learning is still oriented to educators (teacher centered). So far, educators have not been able to handle it properly. As it is known that critical thinking skills have become a curriculum demand in elementary schools to deal with complex life (Rachmadtullah, 2015; Septikasari & Frasandy, 2018; Sukmana, 2018).

Efforts that can be made to overcome the low critical thinking skills of fifth-grade elementary school students in Lampung Province are by applying the integrated Science, Technology, Engineering, and Mathematics (STEM) approach to Project Based Learning (PjBL). Knowledge learned through the STEM approach is most useful in the daily lives of students and gives different meanings in its implementation (Ritz & Fan, 2015). The STEM approach is a learning approach that integrates knowledge of science, technology, engineering, mathematics in a learner-centered learning environment to be taught how to investigate engineering-related problems and find solutions and then build evidence-based on explanations relating to real-world phenomena (Changpetch & Seechaliao, 2020; Crotty et al., 2017; Shernoff et al., 2017).

The implementation of the STEM approach is the best way that is implemented in learning in elementary schools to improve children's critical thinking skills. This is because the STEM approach can foster active, meaningful, and creative learning where the four scientific aspects are needed simultaneously to solve problems in everyday life. The implementation of learning is under the steps of the STEM approach which consists of reflection, research, discovery, application, communication (Khairiyah, 2019). The STEM approach can create quality learning in student-centered schools so that the output produced is under the learning objectives.

The implementation of the STEM approach in developed countries such as the USA has a real impact on the development of students to be active, innovative, creative, productive, and excelling in schools (Kocakaya & Ensari, 2018; Oktapiani & Hamdu, 2020; Permanasari, 2016; Wang & Chiang, 2020). In addition, students who get learning with the STEM approach will form a sense of confidence to always contribute to the development of technological literacy (Prismasari et al., 2019; Salar, 2021). The purpose of the STEM approach in learning in elementary schools is so that students can develop cognitive, affective, psychomotor and can form awareness of STEM disciplines that create intellectual intelligence and human culture (Haryanti & Suwarma, 2018; Jauhariyyah, et al., 2018).

Learning with the STEM approach can be applied to mathematics subjects. Hidayati (2017) mentions that mathematics has an important role in the growth of children's critical thinking skills through the process of learning activities. The benefits obtained from learning mathematics are that it can form a systematic, logical, critical, and careful mathematical mindset (Azizah, et al., 2018; Karso, et al., 2010). When students learn mathematics, they also learn how to construct their thoughts. Based on this, students need to be trained to think at a high level, namely critical thinking.

The previous research on critical thinking skills, namely the research of Putranta, et al. (2019), showed a difference with our research which lies in the use of PhET simulations to improve critical thinking skills. The results of increasing students' critical thinking skills are obtained an average N-gain value of 0.61 (medium category). Furthermore, research by

Parno, et al. (2020) on "The effectiveness of STEM approach on students' critical thinking ability in the topic of fluid statics" shows that 7E LC and STEM-Based 7E LC models significantly affect the improvement of participants' critical thinking skills. And research by Selisne, et al. (2019) on the "Role of learning module in STEM approach to achieve competence of physics learning" shows that using modules with the STEM approach is effective for increasing student competence consisting of knowledge, attitudes, and skills. This study aims to determine the application of the STEM approach to the critical thinking skills of fifth-grade elementary school students in Lampung Province.

Comment [A6]: Describe the novelty in this research

Methods

The type of research used is experimental research, Triyono (2013) explains that experimental research is deliberately made by researchers and there are controls and conditions regulated by researchers. The research method used is a quasi-experimental design (Sugiyono, 2015). The variables contained in this study consisted of two independent variables (STEM approach) and the dependent variable (critical thinking skills).

The fifth-grade elementary schools in Lampung Province were selected as experimental and non-experimental classes. The experimental class (n = 29 students) used the STEM approach, while the non-experimental class (n = 30 students) do not use the STEM approach. Then, the experimental and non-experimental classes will be assessed and compared to see the cause and effect and its effect on the variables given the treatment. Critical thinking skills data was measured using a test instrument. The test refers to an indicator of critical thinking skills known as FRISCO.

Comment [A7]: who is referred for this indicator

The researcher made six test questions in the form of essays to measure the critical thinking skills of fifth-grade students. The questions are made according to the indicators of critical thinking skills. Previously, the researcher had tested the test instrument on 22 students who had the same topic. The researcher then started the study by giving a pre-test before being given the STEM approach. After that, the students were given the STEM approach treatment and at the end of the lesson, the researcher gave a post-test to see the results of the STEM approach treatment (see Table 1).

Table 1. The procedure of a quasi-experimental design.

O_1	X_1	O_2
O_3	X_2	O_4

Note:

O_1 = Pre-test value in the experimental class,
O_2 = Post-test value in the experimental class,
O_3 = Pre-test value in the non-experimental class,
O_4 = Post-test value in the non-experimental class,
X_1 = Treatment using the STEM approach,
X_2 = Treatment without using the STEM approach (Sugiyono, 2015)

Then the normality test is calculated using the following Kolmogorov Smirnov formula with table pattern:

No	Xi	$Z = \frac{Xi-\bar{X}}{SD}$	F_T	F_S	$\lvert F_T - F_S \rvert$
1					
2					
etc					

Comment [A8]: These sentences should be combined into effective and informative sentences

Comment [A9]: References Source should be written in text description

Comment [A10]: What number table?

Comment [A11]: The table should have a title

Note:

Xi	=	The number in the data,
Z	=	The transformation from number to notation in the normal distribution,
FT	=	The normal cumulative probability,
FS	=	The empirical cumulative probability (Nurudin et al., 2014)

ResultsandDiscussion

Comment [A12]: The discussion should refer to the critical thinking indicator (FRISCO)

The results of the measurement of the average value of the pre-test and post-test results of students' critical thinking skills in the experimental class and non-experimental class can be seen in Table 2.

Table 2. Average pre-test and post-test results for the experimental class and the non-experimental class.

No	Aspect description	Experimental		Non-experimental	
		Pre test	Post test	Pre test	Post test
1	Number of students	29	29	30	30
2	Total value	1904,174	2000,08	1712,510	1837,511
3	Averages	65,661	68,965	57,084	61,250

Comment [A13]: Tables are presented according to the rules of writing in scientific articles

Table 2 shows that the average post-test result of the experimental class's critical thinking ability after applying the STEM approach is greater than the average result of the non-experimental class pre-test. If depicted in the graph, the average results of critical thinking skills are shown in Figure 1. The bar chart of the average pre-test and post-test results for the experimental class and the non-experimental class can be seen in Figure 1.

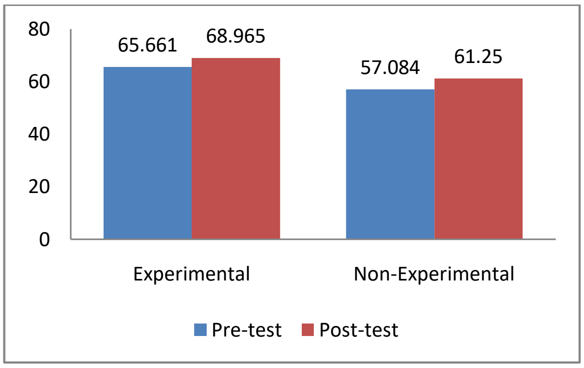

Figure 1. Bar chart of the average pre-test and post-test scores for the experimental class and the non-experimental class.

Students who apply the STEM approach can form an awareness of STEM disciplines that create intellectual intelligence and human culture, so that what students learn at school is easier to absorb (Haryanti & Suwarma, 2018). Meanwhile, students who did not receive the STEM approach were less able to construct their thoughts, especially in mathematics. This can be seen in the examples of students' answers in the experimental and non-experimental classes shown in Figures 2 and 3.

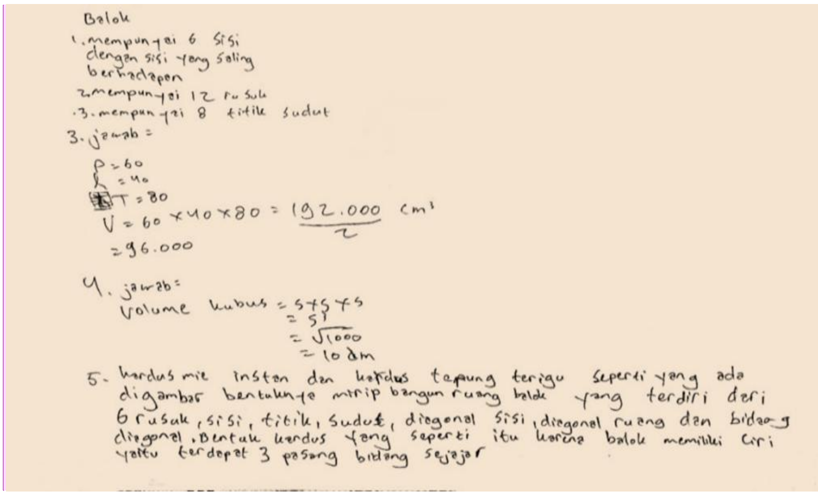

Figure 2. Examples of students' answers in the experimental class.

Comment [A14]: The answer should have an English version

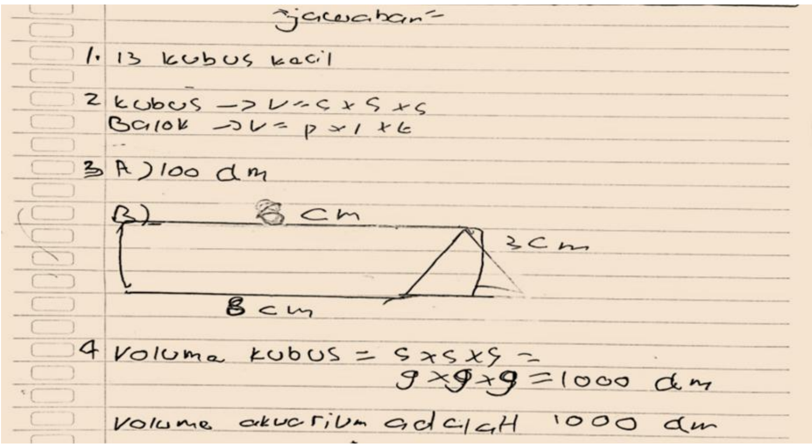

Figure 3. Examples of students' answers in the non-experimental class.

Based on the examples of students' answers between the experimental and non-experimental classes, there are differences, including (1) experimental class students are better at answering the questions given; (2) experimental class students gave detailed answers than the non-experimental class; and (3) experimental class students better understand the questions given than the non-experimental class. These differences indicate that the experimental class students meet the criteria for critical thinking skills. This is relevant to similar research on critical thinking skills by other researchers, namely Afriana et al. (2016) and Lestari (2020).

Normality test is useful to find out whether a data is normally distributed or not. The data tested for normality consisted of initial and final data from the results of the experimental and non-experimental critical thinking skills. Normality test using *Kolmogorov Smirnov* with probability α = 0.05. The results of the analysis of the normality test on the pre-test data obtained a table value of 0.246. So that the largest |FT - FS| < table value (0.160 < 0.246) means that the pre-test data on critical thinking ability of the experimental class is normally distributed (see Table 3).

Table 3. The results of the normality test (pre-test) of critical thinking skills.

No	***Xi***	***F***	***F kum***	***Fs(x)***	***Mean***	***Deviasi Standar***	***Z***	***Ft(x)***	***Fs(x)-Ft(x)***	***|Fs(x)-Ft(x)|***
1	45,5	3	3	0,103	65,661	15,050	-1,339	0,090	0,013	0,013
2	55,5	8	11	0,379	65,661	15,050	-0,675	0,249	0,130	0,130
3	65,5	8	19	0,655	65,661	15,050	-0,012	0,495	0,160	0,160
4	75,5	5	24	0,827	65,661	15,050	0,653	0,743	0,084	0,084
5	85,5	3	27	0,931	65,661	15,050	1,318	0,906	0,025	0,025
6	95,5	2	29	1,000	65,661	15,050	1,982	0,976	0,024	0,024

Comment [A15]: Tables are presented according to the rules of writing in scientific articles

Comment [A16]: Comma (,) or (.)??

The results of the analysis of the normality test to the post-test data obtained a table value of 0.246. So that the largest $|FT - FS|$<table value (0.111 < 0.246) means that the final observation data (post-test) of the experimental class's critical thinking ability is normally distributed (see Table 4).

Table 4. The results of the normality test (post-test) of critical thinking skills.

No	***Xi***	***F***	***F kum***	***Fs(x)***	***Mean***	***Deviasi Standar***	***Z***	***Ft(x)***	***Fs(x)-Ft(x)***	***|Fs(x)-Ft(x)|***
1	45,5	4	4	0,103	68,966	14,502	-1,618	0,052	0,085	0,085
2	55,5	3	7	0,379	68,966	14,502	-0,928	0,176	0,064	0,064
3	65,5	8	15	0,655	68,966	14,502	-0,239	0,405	0,111	0,111
4	75,5	7	22	0,827	68,966	14,502	0,450	0,673	0,084	0,084
5	85,5	5	27	0,931	68,966	14,502	1,140	0,872	0,058	0,058
6	95,5	2	29	1,000	68,966	14,502	1,829	0,966	0,033	0,033

Comment [A17]: Tables are presented according to the rules of writing in scientific articles

Hypothesis testing is done by using r_{table}. If $r_{counts} > r_{table}$ with dengan $\alpha = 0.05$ then Ha is accepted, and if $r_{counts} > r_{table}$ then Ha is rejected. It was found that r_{counts} 0.685 with N = 29 for = 0.05 obtained r_{table} 0.367; so that are $r_{counts} > r_{table}$ (0.685 > 0.367) and the hypothesis is accepted.

The average post-test score of students after applying learning with the STEM approach was higher than the pre-test score. The implementation of learning with a STEM approach can improve students' critical thinking skills in elementary schools and provide meaningful experiences for their lives in the future (Davidi et al., 2021). In addition, learning with the STEM approach taught in elementary schools can have a positive impact on children's development, one of which is the result of creativity by making various crafts as a result of learning the STEM approach in the form of a pencil box by applying the concept of building cubes and blocks as shown in Figure 4.

Figure 4. The results of students' work through STEM approach learning.

Through the STEM approach, students will automatically form a collaborative spirit and creativity in the learning process that integrates four disciplines, namely science, technology, engineering, and mathematics to be able to think critically and solve problems (Falentina, 2018). The benefits obtained by applying learning with the STEM approach in elementary schools are that it can support the skills of students in the 21st century through the learning process, students are able to solve problems well, and can improve students' critical thinking skills through project-based digital literacy (Maula & Fatmawati, 2020).

The hallmark of learning with the STEM approach is that students are required to be actively involved in the learning process and require students to be able to integrate various STEM knowledge which then constructs their thinking so that they can think critically (Sasmita & Hartoyo, 2020). The STEM approach needs to be taught through concrete and contextual things. Because the level of thinking elementary school age students has not been able to think abstractly. The four aspects of STEM in learning are able to improve critical thinking skills. The achievement of increasing critical thinking skills is due to a predetermined indicator.

Comment [A18]: Describe the findings and contributions to science as a result of this research

The increase in students' critical thinking skills indicates the success of the application of the integrated project-based learning (PjBL) STEM approach. This needs to be maintained through a learning process in which educators must be able to foster students to work independently, creatively, innovatively against the various challenges of life. With the STEM approach taught in schools, it provides a learning innovation for the world of education that aims to develop students' critical thinking patterns (Ulfa et al., 2019). Although there are some short comings in the implementation of learning, for example, educators are not familiar teaching with the STEM approach and the advantages are that students are more enthusiastic about learning, active, and creative.

Conclusion

Comment [A19]: Again, first, introduce the work and then briefly state the major results. Then state the major points of the discussion. Finally, end with a statement of how this work contributes to the overall field of study. What's the theoritically and practically implications

In brief, this research concluded that the STEM approach in learning influence the critical thinking skills of fifth-grade students in Lampung Province. The results show that there is a significant effect between learning by the STEM approach on critical thinking skills, it prove that the average final result of critical thinking skills of students in the experimental class is greater than the non-experimental class. The experimental class (68.695) and the non-experimental class (61.250). The data analyze using Kolmogorov Smirnov with the largest | *FT-FS* | t test < table value of 0.111 < 0.246. The students who have been given the STEM approach in learning more careful and detail in understanding and answering the questions than students who do not receive the STEM approach.

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Acknowledgements

The authors would like to thank the University of Lampung, which has given permission to conduct research on the effect of STEM approach learning on the critical thinking skills of fifth grade elementary school students.

Comment [A20]: Acknowledgments also for the school where the research was conducted

References

Comment [A21]: Reference writing should use the Mendeley app

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REFEREE COMMENT 2

The implementation of the STEM approach in learning to the critical thinking skills of fifth-grade elementary school students in Lampung Province

Nelly ASTUTI[1], Riswandi[2], Ujang EFENDI[3] and Nur Ridha UTAMI[4]
Elementary School Teacher Education, Faculty of Teacher Training and Education, University of Lampung, INDONESIA

Corresponding Author's E-mail:nelly.astuti@fkip.unila.ac.id

Abstract

Critical thinking skills is an important aspect of the learning process in the 21st-century era. It can be improved with the Science, Technology, Engineering, and Mathematics (STEM) approach in learning. This study aims to analyze the implementation of the STEM approach in learning to the critical thinking skills of fifth-grade elementary school students in the province of Lampung. The benefits of this research are (1) being able to improve students' critical thinking skills through the STEM approach, (2) the integration of the four aspects of the STEM approach can create active, innovative, and logical thinking students, (3) as a renewal and innovation in learning so that learning is oriented to students, and (4) the STEM approach can be used as an input for learning in primary school. This study uses a quasi-experimental design with experimental and non-experimental classes. The population of this study amounted to 59 students and the research sample amounted to 29 students. The data was obtained using a test in the form of an essay which consist of 6 questions. Items measure critical thinking skills with six indicators, namely focus, reason, inference, situation, clarity, and overview. The reliability of the items in the high category (0.65) and the validity of the items in the moderate to very high category (0.44-0.95). The difference in the test results of the experimental class is 68.695 and the non-experimental class is 61.250. Data analysis using Kolmogorov Smirnov with the largest|FT-FS|t-test < table value of 0.111< 0.246. The results showed that the critical thinking ability was significantly higher in the experimental class students than in the non-experimental class. In conclusion, the results of the research on the critical thinking skills of fifth-grade elementary school students in Lampung Province were influenced by the STEM approach with a significance level of 0.111 (sig <5%). The implementation of the STEM approach in learning plays an important role in improving the critical thinking skills of fifth-grade students.

Keywords: critical thinking skills, STEM approach.

Introduction

21st century skills in the world of education are skills that must be mastered by every student and even become essential to the progress of education in Indonesia. These skills are being able to think critically and problem-solving, learning and innovating skills, collaboration, communicating effectively, analyzing information, and having life skills (Wijaya et al., 2016; Zubaidah, 2016). Various skills are pursued by all elements of education so that students can compete with other countries and are ready to face life's challenges (Astutik & Hariyati, 2021; Nuryanti et al., 2018). Students in primary schools need to be supported to have 21st century skills such as critical thinking skills.

Critical thinking skills play an important role in today's life aspects (Erikson & Erikson, 2019; Halpern, 2014; Prajapati et al., 2017). Every problem that students encounter will be easily overcome if they can think critically. Critical thinking ability is a person's ability to think that is fundamental, reasonable, and reflective which includes activities to analyze, synthesize, create, identify questions, and be able to make logical conclusions and characterize 21st century learning (Asyari et al., 2016; Ennis, 2011; Mahanal et al., 2019; Mardliyah, 2019; Schmaltz et al., 2017). Critical thinking skills are also part of the mental process that teaches how to understand events and environmental conditions (Zubaidah et al., 2018). Someone who can think critically will look different as if he has high curiosity. Changwong et al. (2018) and Cintamulya (2019) state the importance of critical thinking skills, which are needed to help students conceptualize themselves to be active, skilled, find problems, collect data, make hypotheses, and apply all positive things learned.

Critical thinking skills transfer knowledge from one domain to another and educators teach how these abilities can develop efficiently and contribute in every field (Zohar et al., 1994). The effectiveness of a person's critical thinking ability needs an indicator to determine the achievement of a predetermined target. Ennis (2011) revealed six indicators of critical thinking skills called Focus, Reason, Inference, Situation, Clarity, Overview (FRISCO). The six indicators of critical thinking skills provide a broad and useful range of knowledge for students. So, by the six indicators, they are hoped to be a reference in measuring students' critical thinking skills.

In fact, the conditions that occur in elementary schools today are students' low critical thinking skills. This problem is because learning is still oriented to educators (teacher centered). So far, educators have not been able to handle it properly. As it is known that critical thinking skills have become a curriculum demand in elementary schools to deal with complex life (Rachmadtullah, 2015; Septikasari & Frasandy, 2018; Sukmana, 2018).

Efforts that can be made to overcome the low critical thinking skills of fifth-grade elementary school students in Lampung Province are by applying the integrated Science, Technology, Engineering, and Mathematics (STEM) approach to Project Based Learning (PjBL). Knowledge learned through the STEM approach is most useful in the daily lives of students and gives different meanings in its implementation (Ritz & Fan, 2015). The STEM approach is a learning approach that integrates knowledge of science, technology, engineering, mathematics in a learner-centered learning environment to be taught how to investigate engineering-related problems and find solutions and then build evidence-based on explanations relating to real-world phenomena (Changpetch & Seechaliao, 2020; Crotty et al., 2017; Shernoff et al., 2017).

The implementation of the STEM approach is the best way to learn in elementary schools to improve children's critical thinking skills. This is because the STEM approach can foster active, meaningful, and creative learning where the four scientific aspects are simultaneously needed to solve everyday life problems. The implementation of learning is under the steps of the STEM approach which consists of reflection, research, discovery, application, communication (Khairiyah, 2019). The STEM approach can create quality learning in student-centered schools so that the output produced is under the learning objectives.

The implementation of the STEM approach in developed countries such as the USA has a real impact on the development of students to be active, innovative, creative, productive, and excelling in schools (Kocakaya & Ensari, 2018; Oktapiani & Hamdu, 2020; Permanasari, 2016; Wang & Chiang, 2020). In addition, students who get learning with the STEM approach will form a sense of confidence to always contribute to the development of technological literacy (Prismasari et al., 2019; Salar, 2021). The purpose of the STEM approach in learning in elementary schools is to develop cognitive, affective, psychomotor skills and form awareness of STEM disciplines that create intellectual intelligence and human culture (Haryanti & Suwarma, 2018; Jauhariyyah, et al., 2018).
Learning with the STEM approach can be applied to mathematics subjects. Hidayati (2017) mentions that mathematics has an important role in the growth of children's critical thinking skills through learning activities. The benefits obtained from learning mathematics are that it can form a systematic, logical, critical, and careful mathematical mindset (Azizah, et al., 2018; Karso, et al., 2010). When students learn mathematics, they also learn how to construct their thoughts. Based on this, students need to be trained to think highly, namely critical thinking.

The previous research on critical thinking skills, namely the research of Putranta, et al. (2019), showed a difference with our research which lies in the use of PhET simulations to improve critical thinking skills. The results of increasing students' critical thinking skills are obtained an average N-gain value of 0.61 (medium category). Furthermore, research by Parno, et al. (2020) on "The effectiveness of STEM approach on students' critical thinking ability in the topic of fluid statics" shows that 7E LC and STEM-Based 7E LC models significantly affect the improvement of participants' critical thinking skills. And research by Selisne, et al. (2019) on the "Role of learning module in STEM approach to achieve competence of physics learning" shows that using modules with the STEM approach effectively increases student competence consisting of knowledge, attitudes, and skills. This study aims to determine the application of the STEM approach to the critical thinking skills of fifth-grade elementary school students in Lampung Province.

Comment [A22]: No need to show the title of the publication in the narration of the article

Methods

The type of research used is experimental research, Triyono (2013) explains that researchers deliberately make experimental research and there are controls and conditions regulated by researchers. The research method used is a quasi-experimental design (Sugiyono, 2015). The variables contained in this study consisted of two independent variables (STEM approach) and the dependent variable (critical thinking skills).

The fifth-grade elementary schools in Lampung Province were selected as experimental and non-experimental classes. The experimental class (n = 29 students) used the STEM approach, while the non-experimental class (n = 30 students) do not use the STEM approach. Then, the experimental and non-experimental classes will be assessed and compared to see the cause and effect and its effect on the variables given the treatment. Critical thinking skills data was measured using a test instrument. The test refers to an indicator of critical thinking skills known as FRISCO.

Comment [A23]: What is the name of the school?

The researcher made six test questions in the form of essays to measure the critical thinking skills of fifth-grade students. The questions are made according to the indicators of critical thinking skills. Previously, the researcher had tested the test instrument on 22 students who had the same topic. The researcher then started the study by giving a pre-test before being given the STEM approach. After that, the students were given the STEM approach treatment and at the end of the lesson, the researcher gave a post-test to see the results of the STEM approach treatment (see Table 1).

Comment [A24]: The questions in the appendix have not addressed all aspects of FRISCO.
How about the validity and reliability of the questions?

Comment [A25]: The subject of learning is mathematics and has not shown all the elements of STEM, still focuses on the subject of mathematics, and has not shown its STE elements.

Table 1. The procedure of a quasi-experimental design.

O_1	X_1	O_2
O_3	X_2	O_4

Note:

O_1 = Pre-test value in the experimental class,
O_2 = Post-test value in the experimental class,
O_3 = Pre-test value in the non-experimental class,
O_4 = Post-test value in the non-experimental class,
X_1 = Treatment using the STEM approach,
X_2 = Treatment without using the STEM approach (Sugiyono, 2015)

Then the normality test is calculated using the following Kolmogorov Smirnov formula with table pattern:

Comment [A26]: There is no need to show the normality formula because this is a standard formula, just mention the Kolmogorov Smirnov test.

No	*Xi*	$Z = \frac{Xi - \bar{X}}{SD}$	F_T	F_S	$\lvert F_T - F_S \rvert$
1					
2					
etc					

Note:

Xi = The number in the data,
Z = The transformation from number to notation in the normal distribution,
FT = The normal cumulative probability,
FS = The empirical cumulative probability (Nurudin et al., 2014)

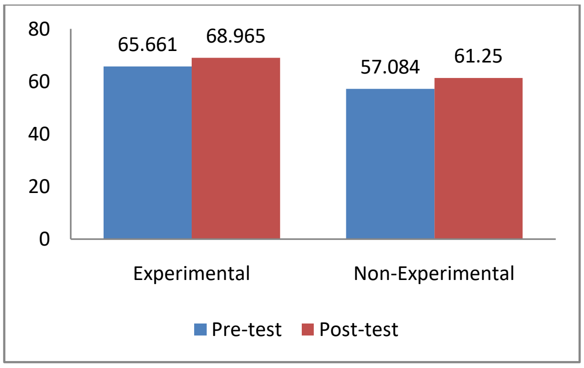
ResultsandDiscussion

The results of the measurement of the average value of the pre-test and post-test results of students' critical thinking skills in the experimental class and non-experimental class can be seen in Table 2.

Table 2. Average pre-test and post-test results for the experimental class and the non-experimental class.

No	Aspect description	Experimental		Non-experimental	
		Pre test	Post test	Pre test	Post test
1	Number of students	29	29	30	30
2	Total value	1904,174	2000,08	1712,510	1837,511
3	Averages	65,661	68,965	57,084	61,250

Table 2 shows that the average post-test result of the experimental class's critical thinking ability after applying the STEM approach is greater than the average result of the non-experimental class pre-test. If depicted in the graph, the average results of critical thinking skills are shown in Figure 1. The bar chart of the average pre-test and post-test results for the experimental and non-experimental classes can be seen in Figure 1.



Comment [A27]: How are the experimental and non-experimental classes equivalent? Are the two classes really equal? The two classes should be tested for equality first.

If you look at the average score increase, the non-experimental class is actually better than the experimental class.
Experimental class: 68.965-65.661= 3.304
Non-experimental class: 61.250-57,084 = 4.166 (higher than experimental class)

It seems that since the beginning of the experimental class, the test scores have gotten better. However, if you look at the average increase, the non-experimental class is actually better.

Comment [A28]: In Figure 1 it can be seen that the experimental class from the beginning was indeed higher than the non-experimental class. So it cannot be justified that the experimental class is better than the non-experimental class.

Figure 1. Bar chart of the average pre-test and post-test scores for the experimental and non-experimental classes.

Students who apply the STEM approach can form an awareness of STEM disciplines that create intellectual intelligence and human culture, so that what students learn at school is easier to absorb (Haryanti & Suwarma, 2018). Meanwhile, students who did not receive the STEM approach were less able to construct their thoughts, especially in mathematics. This can be seen in the examples of students' answers in the experimental and non-experimental classes shown in Figures 2 and 3.

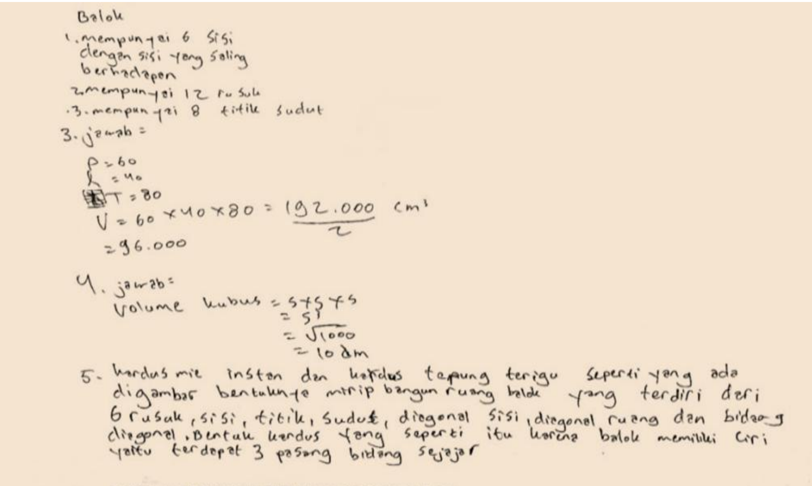


Figure 2. Examples of students' answers in the experimental class.

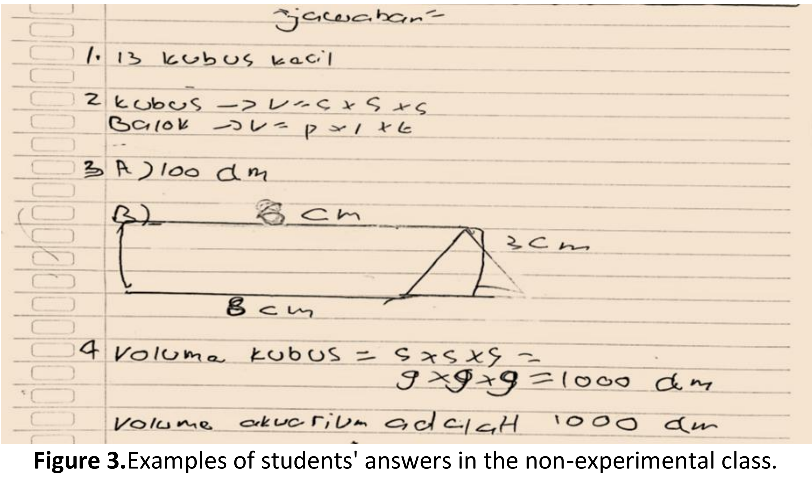


Figure 3. Examples of students' answers in the non-experimental class.

Based on the examples of students' answers between the experimental and non-experimental classes, there are differences, including (1) experimental class students are better at answering the questions given; (2) experimental class students gave detailed answers than the non-experimental class; and (3) experimental class students better understand the questions given than the non-experimental class. These differences indicate that the experimental class students meet the criteria for critical thinking skills. This is relevant to similar research on critical thinking skills by other researchers, namely Afriana et al. (2016) and Lestari (2020).

Normality test is useful to find out whether a data is normally distributed or not. The data tested for normality consisted of initial and final data from the results of the experimental and non-experimental critical thinking skills. Normality test using *Kolmogorov Smirnov* with probability α = 0.05. The results of the analysis of the normality test on the pre-test data obtained a table value of 0.246. So that the largest |FT - FS| < table value (0.160 < 0.246) means that the pre-test data on critical thinking ability of the experimental class is normally distributed (see Table 3).

Table 3. The results of the normality test (pre-test) of critical thinking skills.

No	*Xi*	*F*	*F kum*	*Fs(x)*	*Mean*	*Deviasi Standar*	*Z*	*Ft(x)*	*Fs(x)-Ft(x)*	*|Fs(x)-Ft(x)|*
1	45,5	3	3	0,103	65,661	15,050	-1,339	0,090	0,013	0,013
2	55,5	8	11	0,379	65,661	15,050	-0,675	0,249	0,130	0,130
3	65,5	8	19	0,655	65,661	15,050	-0,012	0,495	0,160	0,160
4	75,5	5	24	0,827	65,661	15,050	0,653	0,743	0,084	0,084
5	85,5	3	27	0,931	65,661	15,050	1,318	0,906	0,025	0,025
6	95,5	2	29	1,000	65,661	15,050	1,982	0,976	0,024	0,024

Comment [A29]: The comma (,) in English text should be changed to a point (.)

The results of the analysis of the normality test to the post-test data obtained a table value of 0.246. So that the largest |*FT - FS*| < table value (0.111 < 0.246) means that the final observation data (post-test) of the experimental class's critical thinking ability is normally distributed (see Table 4).

Table 4. The results of the normality test (post-test) of critical thinking skills.

No	*Xi*	*F*	*F kum*	*Fs(x)*	*Mean*	*Deviasi Standar*	*Z*	*Ft(x)*	*Fs(x)-Ft(x)*	*|Fs(x)-Ft(x)|*
1	45,5	4	4	0,103	68,966	14,502	-1,618	0,052	0,085	0,085
2	55,5	3	7	0,379	68,966	14,502	-0,928	0,176	0,064	0,064
3	65,5	8	15	0,655	68,966	14,502	-0,239	0,405	0,111	0,111
4	75,5	7	22	0,827	68,966	14,502	0,450	0,673	0,084	0,084
5	85,5	5	27	0,931	68,966	14,502	1,140	0,872	0,058	0,058
6	95,5	2	29	1,000	68,966	14,502	1,829	0,966	0,033	0,033

Hypothesis testing is done by using r_{table}. If $r_{counts} > r_{table}$ with dengan α = 0.05 then Ha is accepted, and if $r_{counts} > r_{table}$ then Ha is rejected. It was found that r_{counts} 0.685 with N = 29 for = 0.05 obtained r_{table} 0.367; so that are $r_{counts} > r_{table}$ (0.685 > 0.367) and the hypothesis is accepted.

The average post-test score of students after applying learning with the STEM approach was higher than the pre-test score. The implementation of learning with a STEM approach can improve students' critical thinking skills in elementary schools and provide meaningful experiences for their lives in the future (Davidi et al., 2021). In addition, learning with the STEM approach taught in elementary schools can have a positive impact on children's development, one of which is the result of creativity by making various crafts as a result of learning the STEM approach in the form of a pencil box by applying the concept of building cubes and blocks as shown in Figure 4.

Figure 4. The results of students' work through STEM approach learning.

Through the STEM approach, students will automatically form a collaborative spirit and creativity in the learning process that integrates four disciplines, namely science, technology, engineering, and mathematics, to think critically and solve problems (Falentina, 2018). The benefits obtained by applying learning with the STEM approach in elementary schools are that it can support the skills of students in the 21st century through the learning process, students are able to solve problems well, and can improve students' critical thinking skills through project-based digital literacy (Maula & Fatmawati, 2020).

The hallmark of learning with the STEM approach is that students are required to be actively involved in the learning process and require students to be able to integrate various STEM knowledge which then constructs their thinking so that they can think critically (Sasmita & Hartoyo, 2020). The STEM approach needs to be taught through concrete and contextual things. Because the level of thinking elementary school age students has not been able to think abstractly. The four aspects of STEM in learning are able to improve critical thinking skills. The achievement of increasing critical thinking skills is due to a predetermined indicator.

Comment [A30]: How is the explanation of the FRISCO indicator from the questions given and from the resulting product?

The increase in students' critical thinking skills indicates the success of the application of the integrated project-based learning (PjBL) STEM approach. This needs to be maintained through a learning process in which educators must be able to foster students to work independently, creatively, innovatively against the various challenges of life. The STEM approach taught in schools provides a learning innovation for the world of education that aims to develop students' critical thinking patterns (Ulfa et al., 2019). Although there are some short comings in the implementation of learning, for example, educators are not familiar with the STEM approach. The advantages are that students are more enthusiastic about learning, active, and creative.

Conclusion

In brief, this research concluded that the STEM approach in learning influence the critical thinking skills of fifth-grade students in Lampung Province. The results show that there is a significant effect between learning by the STEM approach on critical thinking skills, it prove that the average final result of critical thinking skills of students in the experimental class is greater than the non-experimental class. The experimental class (68.695) and the non-experimental class (61.250). The data analyze using Kolmogorov Smirnov with the largest $|FT\text{-}FS|$ t test < table value of 0.111 < 0.246. The students who have been given the STEM approach in learning more careful and detail in understanding and answering the questions than students who do not receive the STEM approach.
`

Acknowledgements

The authors would like to thank the University of Lampung, which has permitted to research the effect of STEM approach learning on the critical thinking skills of fifth grade elementary school students.

References

Comment [A31]: The majority of references are in Indonesian. Preferably for international journals, authors use international language references.

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Second Referee's Report

Article Title: The implementation of the STEM approach in learning to the critical thinking skills of fifth-grade elementary school students in Lampung Province

1. Quality of content:

( ) Outstanding

( ) Good

( ) Average

( ) Marginal

(X) Below the acceptable level

2. Quality of presentation:

( ) Outstanding

( ) Good

( ) Average

(X) Marginal

( ) Below the acceptable level

3. Recommendation:

( ) Accepted for publication without change.

( ) Accepted for publication after minor revisions mentioned in the comments.

( ) Major revisions are necessary.

(X) Do not publish.

( ) Manuscript may be more appropriate for another journal (please specify):

( ) Other; see comments.

4. Section for publication (if accepted):

( ) **General Articles** section which is reserved for professional articles (not formal research papers) on pilot research, some teaching methods/ideas/practices, issues in science education or curriculum.

( ) **Academic Articles** section which is reserved for original research or review articles.

5. Comments for feedback to the author(s):

The paper is seem need much revise. The author must try to revise in each part of paper. For example:

- No need to show the title of the publication in the narration of the article
- The questions in the appendix have not addressed all aspects of FRISCO. How about the validity and reliability of the questions?
- The subject of learning is mathematics and has not shown all the elements of STEM, still focuses on the subject of mathematics, and has not shown its STE elements yet.
- There is no need to show the normality formula because this is a standard formula, just mention the Kolmogorov Smirnov test.
- How are the experimental and non-experimental classes equivalent? Are the two classes really equal? The two classes should be tested for equality first.

  If you look at the average score increase, the non-experimental class is actually better than the experimental class.

  Experimental class: 68.965-65.661= 3.304

  Non-experimental class: 61.250-57,084 = 4.166 (higher than experimental class)

  It seems that since the beginning of the experimental class, the test scores have gotten better. If you look at the average increase, the non-experimental class is actually better.
- In Figure 1 it can be seen that the experimental class from the beginning was indeed higher than the non-experimental class. So it cannot be justified that the experimental class is better than the non-experimental class.
- How is the explanation of the FRISCO indicator from the questions given and from the resulting product?
- The majority of references are in Indonesian. Preferably for international journals, authors use international language references.
- Other suggestions can be found in the manuscript.

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RESPONSE TO REVIEWER

1st Referee Comments

1st Referee, Comment #1:

The title of paper typing in sentence case, without Acronym or abbreviation.

Author Response:

Thank you for your careful reviewing. All your comments and suggestions all very helpful and useful for improving our paper.

Author Action:

We've fixed the post title without acronyms.

1st Referee, Comment #2:

This number of students can be used as a sample.

Author Response:

Thank you for your careful reviewing.

Author Action:

We have fixed this number of students to use as a sample. Overall, the population in elementary schools is 311 students and the sample is 59 students.

1stReferee, Comment #3:

the sample used is not representative.

Author Response:

Thank you for your careful reviewing.

Author Action:

We have corrected the sample to be representative, namely 59 students.

1st Referee, Comment #4, Comment #5:

The use of words must pay attention to consistency.

Author Response:

Thank you for your careful reviewing.

Author Action:

We have corrected the word that should be used in this article to be consistent, namely "skills" not "ability".

1st Referee, Comment#6:

Describe the novelty in this research.

Author Response:

Thank you for your careful reviewing.

Author Action:

We have improved this section, namely the novelty is that students are able to communicate well, collaborate, think critically, and problem solving, creativity and innovation, and are able to face global challenges.

1st Referee, Comment#7:

These sentences should be combined into effective and informative sentences.

Author Response:

Thank you for your careful reviewing.

Author Action:

We have corrected this sentence into an effective and informative sentence (can be seen in the method section).

1st Referee, Comment#8:

who is referred for this indicator.

Author Response:

Thank you for your careful reviewing.

Author Action:

This indicator is referred to the critical thinking ability indicator, namely FRISCO which has been explained in paragraph.

1st Referee, Comment#9:

References Source should be written in text description.

Author Response:

Thank you for your careful reviewing.

Author Action:

We have corrected the location of this source reference in the description text.

1st Referee, Comment#10:

What number table?

Author Response:

Thank you for your careful reviewing.

Author Action:

The revision fix in this article, we do not include the table because it is according to the advice of the 2nd Referee not to show the Kolmogorov smirnov formula. Because this formula is a standard formula.

1st Referee, Comment#11:

The table should have a title.

Author Response:

Thank you for your reviewing.

Author Action:

Improvements to the revision of this comment, we do not include the table title because it is in accordance with the suggestion of the 2nd Referee not to show the Kolmogorov smirnov formula. This formula is a standard formula so it is sufficient to mention it.

1st Referee, Comment#12:

The discussion should refer to the critical thinking indicator (FRISCO).

Author Response:

Thank you for your reviewing.

Author Action:

We have corrected the revision of this comment by discussing in more detail the critical thinking indicator (FRISCO) and can be seen in our article.

1st Referee, Comment#13:

Tables are presented according to the rules of writing in scientific articles.

Author Response:

Thank you for your reviewing.

Author Action:

Improvements to this comment have been improved by following the rules of writing in scientific articles.

Table 2. Average pre-test and post-test results for the experimental class and the non-experimental class.

No	Aspect description	Experimental		Non-experimental	
		Pre test	Post test	Pre test	Post test
1	Number of students	29	29	30	30
2	Total value	1904.174	2000.08	1712.510	1837.511
3	Averages	65.661	68.965	57.084	61.250

1st Referee, Comment#14:

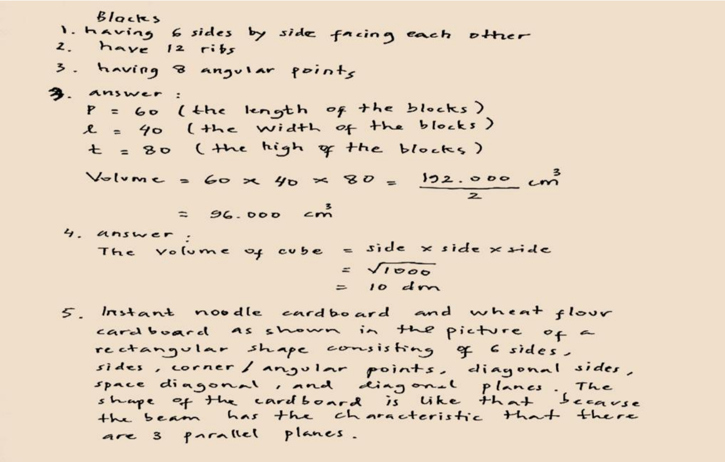
The answer should have an English version.

Author Response:

Thank you for your reviewing.

Author Action:

We have fixed this comment using the English version.



Blocks
1. having 6 sides by side facing each other
2. have 12 ribs
3. having 8 angular points
3. answer :
p = 60 (the length of the blocks)
l = 40 (the width of the blocks)
t = 80 (the high of the blocks)
Volume = 60 × 40 × 80 = $\frac{192.000}{2}$ cm^3
= 96.000 cm^3
4. answer :
The volume of cube = side × side × side
= $\sqrt{1000}$
= 10 dm
5. Instant noodle cardboard and wheat flour cardboard as shown in the picture of a rectangular shape consisting of 6 sides, sides, corner / angular points, diagonal sides, space diagonal, and diagonal planes. The shape of the cardboard is like that because the beam has the characteristic that there are 3 parallel planes.

Figure 2. Examples of students' answers in the experimental class.

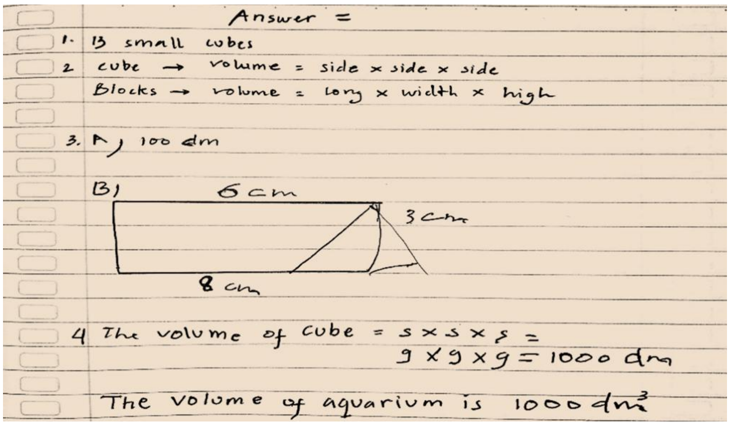


Figure 3. Examples of students' answers in the non-experimental class.

1st Referee, Comment#15:

Tables are presented according to the rules of writing in scientific articles.

Author Response:

Thank you for your reviewing.

Author Action:

Improvements to this comment have been improved by following the rules of writing in scientific articles.

Table 3.The results of the normality test (pre test) of critical thinking skills.

No	*Xi*	*F*	*F kum*	*Fs(x)*	*Mean*	*Standard Deviation*	*Z*	*Ft(x)*	*Fs(x)-Ft(x)*	*│Fs(x)-Ft(x)│*
1	45.5	3	3	0.103	65.661	15.050	-1.339	0.090	0.013	0.013
2	55.5	8	11	0.379	65.661	15.050	-0.675	0.249	0.130	0.130
3	65.5	8	19	0.655	65.661	15.050	-0.012	0.495	0.160	0.160
4	75.5	5	24	0.827	65.661	15.050	0.653	0.743	0.084	0.084
5	85.5	3	27	0.931	65.661	15.050	1.318	0.906	0.025	0.025
6	95.5	2	29	1.000	65.661	15.050	1.982	0.976	0.024	0.024

1st Referee, Comment#16:

Comma (,) or (.)??

Author response:

Thank you for your reviewing.

Author Action:

The fix for this comment is to use a period (.)

1st Referee, Comment#17:

Tables are presented according to the rules of writing in scientific articles.

Author Response:

Thank you for your reviewing.

Author Action:

Improvements to this comment have been improved by following the rules of writing in scientific articles.

Table 4.The results of the normality test (post test) of critical thinking skills.

No	*Xi*	*F*	*F kum*	*Fs(x)*	*Mean*	*Standard Deviation*	*Z*	*Ft(x)*	*Fs(x)-Ft(x)*	*│Fs(x)-Ft(x)│*
1	45.5	4	4	0.103	68.966	14.502	-1.618	0.052	0.085	0.085
2	55.5	3	7	0.379	68.966	14.502	-0.928	0.176	0.064	0.064
3	65.5	8	15	0.655	68.966	14.502	-0.239	0.405	0.111	0.111
4	75.5	7	22	0.827	68.966	14.502	0.450	0.673	0.084	0.084
5	85.5	5	27	0.931	68.966	14.502	1.140	0.872	0.058	0.058
6	95.5	2	29	1.000	68.966	14.502	1.829	0.966	0.033	0.033

1st Referee, Comment#18:

Describe the findings and contributions to science as a result of this research.

Author Response:

Thank you for your reviewing.

Author Action:

Improvements to this comment, we have explained the findings and contributions to science as a result of the research which can be seen in the results and discussion section.

1st Referee, Comment#19:

Again, first, introduce the work and then briefly state the major results. Then state the major points of the discussion. Finally, end with a statement of how this work contributes to the overall field of study. What's the theoritically and practically implications.

Author Response:

Thank you for your reviewing.

Author Action:

We have made improvements to this comment in the conclusion section of the article in accordance with the suggestions from the 1st Referee.

1st Referee, Comment#20:

Acknowledgments also for the school where the research was conducted.

Author Response:

Thank you for your reviewing.

Author Action:

In the revision of this comment have been added in the acknowledgments section, namely Tri Sukses Natar elementary school.

1st Referee, Comment#21:

Reference writing should use the Mendeley app.

Author Response:

Thank you for your reviewing.

Author Action:

In the revision of this comment, we have used the Mendeley app.

2nd Referee 862-1638-1-SP-Review

2nd Referee, Comment#1:

No need to show the title of the publication in the narration of the article.

Author Response:

Thank you for your careful reviewing. All your comments and suggestions all very helpful and useful for improving our paper.

Author Action:

We have corrected this comment by not including the title of the publication in the narration of the article (can be seen in the introduction section).

2nd Referee, Comment#2:

What is the name of the school?

Author Response:

Thank you for your careful reviewing.

Author Action:

We have corrected this comment by mentioning the name of the school where the research was conducted, namely SD Tri Sukses Natar.

2nd Referee, Comment#3:

The questions in the appendix have not addressed all aspects of FRISCO. How about the validity and reliability of the questions?

Author Response:

Thank you for your careful reviewing.

Author Action:

We have made improvements to this comment by discussing the FRISCO, validity, and reliability aspects in detail (can be seen in the methods section).

2nd Referee, Comment#4:

The subject of learning is mathematics and has not shown all the elements of STEM, still focuses on the subject of mathematics, and has not shown its STE elements.

Author Response:

Thank you for your reviewing.

Author Action:

We have corrected this comment by explaining all STEM elements (not just math),can be seen in the methods section.

2nd Referee, Comment#5:

There is no need to show the normality formula because this is a standard formula, just mention the Kolmogorov Smirnov test.

Author Response:

Thank you for your reviewing.

Author Action:

We have fixed this comment by not showing the normality formula, but we only mention it using the Kolmogorov Smirnov formula.

2nd Referee, Comment#6:

How are the experimental and non-experimental classes equivalent? Are the two classes really equal? The two classes should be tested for equality first.

If you look at the average score increase, the non-experimental class is actually better than the experimental class.

Experimental class: 68.965-65.661= 3.304

Non-experimental class: 61.250-57,084 = 4.166 (higher than experimental class)

It seems that since the beginning of the experimental class, the test scores have gotten better. However, if you look at the average increase, the non-experimental class is actually better.

Author response:

Thank you for your reviewing.

Author Action:

Permission to answer for comment#6, that the experimental and non-experimental classes are at the same level. The determination of experimental and non-experimental classes is not based on high and low scores. Both classes have the characteristics of students with the same age and learning needs. It's just that when implementing the STEM approach in learning in the experimental class the average value of the experimental class becomes larger. This research is to see how much the increase in the value given by the STEM approach to those who are not given the STEM approach in classroom learning. It is clear that there is an increase in the value in both classes (experimental and non-experimental). But the experimental class has a higher score from the beginning given the pre-test questions. Although the difference in value is not too much different from the non-experimental class.That's the actual situation that happened during the research in the field.

2nd Referee, Comment#7:

In Figure 1 it can be seen that the experimental class from the beginning was indeed higher than the non-experimental class. So it cannot be justified that the experimental class is better than the non-experimental class.

Author Response:

Thank you for your reviewing.

Author Action:

Permission to answer for comment # 7, that in Figure 1 the experimental class is indeed higher because the experimental class is treated with the STEM approach. So if it is depicted on the graph, then the experimental class is higher than the non-experimental class. As explained in comment #6 that the determination of experimental and non-experimental classes is not based on the high and low grades in school but only the implementation that differs between the two classes during learning.

2nd Referee, Comment#8:

The comma (,) in English text should be changed to a point (.)

Author Response:

Thank you for your reviewing.

Author Action:

We have fixed the improvements to comment #8 by changing the comma (,) to a period (.) according to the rules of writing in scientific articles.

2nd Referee, Comment#9:

How is the explanation of the FRISCO indicator from the questions given and from the resulting product?

Author Response:

Thank you for your reviewing.

Author Action:

Permission to reply to this comment, that we have explained the FRISCO indicator in the paragraphs of the results & discussion section.

The indicator in question is an indicator of critical thinking ability consisting of six, namely focus, reason, inference, situation, clarity, and overview (FRISCO) which is manifested in the form of pre-test and post-test questions. Where *F* (focus) is to introduce students to what should be discussed and identify problems. Furthermore, students need to provide rationally supporting reasons for the existing problems, this is part of the *R* (reason). *I* (inference) is the process of making conclusions based on appropriate arguments based on investigations and evidence that has been obtained. *S* (situation) i.e. when the thinking process focuses on belief and is a decision-making process, it needs to be supported by situations that involve other elements such as the physical and social environment. Another important thing about critical thinking indicators is *C* (clarity) which is the clarity to convey the message to the decisions made. And the last indicator is *O* (overview) which is to review and verify the problems that have been found previously. Based on the six indicators of critical thinking skills, it is useful to measure the extent to which students' critical thinking skills are implemented after the STEM approach in learning and the resulting product is the work of students through the implementation of the STEM approach as shown in Figure 4.

2nd Referee, Comment#10:

The majority of references are in Indonesian. Preferably for international journals, authors use international language references.

Author response:

Thank you for your reviewing.

Author action:

We have added international journals to this reference article as suggested by the 2nd Referee.

REVISI

Implementation of science technology engineering and mathematics approach in learning to critical thinking skills of fifth-grade elementary school students in Lampung Province

Nelly ASTUTI[1], Riswandi[2], Ujang EFENDI[3] and Nur Ridha UTAMI[4]

Elementary School Teacher Education, Faculty of Teacher Training and Education, University of Lampung, INDONESIA

Corresponding Author's E-mail:nelly.astuti@fkip.unila.ac.id

Abstract

Critical thinking skills is an important aspect of the learning process in the 21st-century era. It can be improved with the Science, Technology, Engineering, and Mathematics (STEM) approach in learning. This study aims to analyze the implementation of the STEM approach in learning to the critical thinking skills of fifth-grade elementary school students in the province of Lampung. The benefits of this research are (1) being able to improve students' critical thinking skills through the STEM approach, (2) the integration of the four aspects of the STEM approach can create active, innovative, and logical thinking students, (3) as a renewal and innovation in learning so that learning is oriented to students, and (4) the STEM approach can be used as an input for learning in elementary school. This study uses a quasi-experimental design with experimental and non-experimental classes. The population of this study amounted to 311 studentsand the research sample amounted to 59 students. The data is obtained using a test in the form of an essay whichconsist of 6 questions. Items measure critical thinking skills with six indicators, namely focus, reason, inference, situation, clarity, and overview. The reliability of the items in the high category (0.65) and the validity of the items in the moderate to very high category (0.44-0.95). The difference in the test results of the experimental class is 68.695 and the non-experimental class is 61.250. Data analysis using Kolmogorov Smirnov with the largest|FT-FS|t-test < table value of 0.111< 0.246. The results show that the critical thinking skills is significantly higher in the experimental class students than in the non-experimental class. The results of the research on the critical thinking skills of fifth-grade elementary school students in Lampung Province are influence by the STEM approach with a significance level of 0.111 (sig <5%). Implementation of STEM approach in learning plays an important role in improving the critical thinking skills of fifth-grade students.

Keywords: critical thinking skills, elementary school, learning, STEM approach.

Introduction

21st-century skills in the world of education are skills that must be mastered by every student and even become essential to the progress of education in Indonesia. These skills are being able to think critically and problem-solving, learning and innovating skills, collaboration, communicating effectively, analyzing information, and having life skills(Widana et al., 2018; Wijaya et al., 2016; Zubaidah, 2016). Various skills are pursued by all elements of education so that students can compete with other countries and are ready to face life's challenges (Astutik & Hariyati, 2021; Nuryanti et al., 2018). Students in elementary schools need to be supported to have 21st-century skills such as critical thinking skills.

Critical thinking skills play an important role in today's life aspects (Erikson & Erikson, 2019; Halpern, 2014; Prajapati et al., 2017). Every problem that students encounter will be easily overcome if they can think critically. Critical thinking skillsis a person's ability to think that is fundamental, reasonable, and reflective which includes activities to analyze, synthesize, create, identify questions, and be able to make logical conclusions and characterize 21st-century learning (Asyari et al., 2016; Butterworth & Thwaites, 2013; Ennis, 2011; Mahanal et al., 2019; Mardliyah, 2018; Schmaltz et al., 2017). Critical thinking skills are also part of the mental process that teaches how to understand the events and conditions of environment as well as to acquire new knowledges (Doleck et al., 2017; Zubaidah et al., 2018). Students with critical thinking skills looked different compared to others since their curiousity is high. Critical thinking skills are actually required for students to conceptualize themselves being active, skilled, easy to solve problems, able to collect data and make hypotheses, and applying all their learned knowledges (Changwong et al., 2018; Cintamulya, 2019).

Having critical thinking skills, the students cantransfer knowledge from one domain to another. Furthermore, the educators teach them how these abilities can develop efficiently and contribute to every field(Zohar et al., 1994). The effectiveness of a person's critical thinking skills needs an indicator to determine the achievement of a predetermined target. There are six indicators of critical thinking skills i.e., Focus, Reason, Inference, Situation, Clarity, Overview (FRISCO)(Ennis, 2011).The six indicators of critical thinking skills provide a broad and useful range of knowledge for students. So, by the six indicators, they are expected to be a reference in measuring students' critical thinking skills.

In fact, the conditions that occur in elementary schools today are that the students have low critical thinking skills. This problem is appeared because the learning activity is still oriented to educators as the center of attention (teacher centered mode). So far, educators have not been able to handle it properly. However, it is already known that critical thinking skills have become a curriculum demand in elementary schools to prepare the students dealing with complex life (Rachmadtullah, 2015; Septikasari & Frasandy, 2018; Sukmana, 2018).

The integration STEM approach into Project Based Learning (PjBL) can be applied to overcome the low critical thinking skills of fifth-grade elementary school students in Lampung Province. Knowledge learned through the STEM approach is most useful in the daily lives of students and gives different meanings in its implementation(Ritz & Fan, 2014). The STEM approach is a learning approach that integrates knowledge of STEM in a student-centered learning environment and teach the student how to investigate engineering-related problems and find solutions and then build evidence-based on explanations relating to real-world phenomena(Changpetch & Seechaliao, 2020; Crotty et al., 2017; Shernoff et al., 2017).

The implementation of the STEM approach is the best way to learn in elementary schools to improve children's critical thinking skills(Yaki et al., 2019). This is because the STEM approach can foster active, meaningful, and creative learning where the four scientific aspects are simultaneously acquire to solve daily life problems. The implementation of learning is under the steps of the STEM approach which consists of reflection, research, discovery, application, communication (Khairiyah, 2019). The STEM approach can create quality learning in student-centered schools so that the output produced is under the learning objectives.

In addition, STEM also implemented in developed countries such as USA has a real impact on the development of students to be active, innovative, creative, productive, and excelling in schools(Kocakaya & Ensari, 2018; Oktapiani & Hamdu, 2020; Permanasari, 2016; Wang & Chiang, 2020).Furthermore, students who get learning with the STEM approach will form a sense of confidence to always contribute to the development of technological literacy (Prismasari et al., 2019; Salar, 2021). The purpose of the STEM approach in learning in elementary schools is to develop cognitive, affective, psychomotor skills and to form awareness of STEM disciplines that create intellectual intelligence and human culture (Haryanti & Suwarma, 2018; Jauhariyyah et al., 2017).

Learning with the STEM approach can be applied to mathematics subjects. Mathematics has an important role in the growth of children's critical thinking skills through learning activities(Hidayati, 2017). The benefits obtained from learning mathematics are that it can form a systematic, logical, critical, and careful mathematical mindset (Acar et al., 2018; Azizah et al., 2018; Karso et al., 2010). When students learn mathematics, they also learn how to construct their thoughts. Based on this, students need to be trained to think highly, namely critical thinking.

The previous research on critical thinking skills, such as the research by(Putranta et al., 2019)shows a difference with our research which lies in the use of PhET simulations to improve critical thinking skills. The results of increasing students' critical thinking skills are obtained an average N-gain value of 0.61 (medium category). In addition, research by (Parno et al., 2021)shows that 7E LC and STEM-Based 7E LC models significantly affect the improvement of participants' critical thinking skills. Furthermore,research by (Selisne et al., 2019) shows that using modules with the STEM approach effectively increases student competence consisting of knowledge, attitudes, and skills. This study aims to determine the implementation of the STEM approach to the critical thinking skills of fifth-grade elementary school students in Lampung Province.

Methods

The type of research used is experimental research.Experimental research is that researchers deliberately make experimental research and there are controls and conditions regulated by researchers(Triyono, 2013). The research method used is a quasi-experimental design (Sugiyono, 2015). The variables contained in this study consisted of two independent variables (STEM approach) and the dependent variable (critical thinking skills).

The fifth-grade ofTri Sukses Natarelementary school is selected as experimental and non-experimental classes.The experimental class (n = 29 students) uses the STEM approach, while the non-experimental class (n = 30 students) doesn't use the STEM approach. Then, the experimental and non-experimental classes is assessed and compared to see the cause and effect and its effect on the variables given the treatment. Critical thinking skills data is measured using a test instrument. The test refers to an indicator of critical thinking skills known as FRISCO(Davies & Barnett, 2015; Ennis, 2011).

Based on the indicators of critical thinking skills, the authors made six test questions in the form of essays to measure the critical thinking skills of fifth-grade students. The questions are made according to the indicators of critical thinking skills which consist of FRISCO. Previously, the author perform the instrument test on 22 students at Gedong Air 1 elementary school who have the same criteria as the students of elementary school where the main research is conducted. The six questions is declared valid and reliable with the acquisition of r count > r table. Test the validity of the test instrument using the product moment correlation formula, while the reliability test using the Cronbach Alpha formula(Fraenkel et al., 2012).

It is adjusted to the four aspects of STEM i.e., science, technology, engineering, and mathematics (Guleryuz & Dilber, 2021). Aspects of science are focus learning on shape of objects and force of gravity of the earth which is associated with the subject matter of building cubes and blocks. The students learning outcomes for this aspect are students know and understand that a cube and block is an example of a solid object. The technological aspect is to direct students to apply the knowledge gained into a skill using hardware such as laptops and smartphones to get information that will be useful for designing a product to be produced. This is raised in learning by showing videos about building cubes and blocks using an LCD/projector and laptop.

Following the next aspect is engineering used to trained students to be able in processing and to solve existing problems such as how to design products accurately on it size (Shahali et al., 2017). For example, students make a dice design with the concept of building a cube space and make a pencil box design with the concept of a unit cube. When carrying out engineering aspects in learning, students can indirectly construct their thoughts in designing a project related to their life and also create creativity and improve critical thinking skills. The last for mathematical aspect, student is directed to gain the basic competencies and indicators in learning achievement of fifth-grade that is to analyze the elements of building blocks and cubes. The results are that students become easier to understand the learning of building cubes and blocks, seem more fun by making a project and think logically (Han et al., 2016).

Based on those aspects, the authors started to give pre-test before implementing the STEM approach. So that, the authors treat STEM to the students and at the end of the lesson the authors give a post test to see the results of the STEM approach treatment (Sugiyono, 2015) (see table 1).

Table 1. The procedure of a quasi-experimental design.

O_1	X_1	O_2
O_3	X_2	O_4

Note:

O_1 = Pre-test value in the experimental class,
O_2 = Post-test value in the experimental class,
O_3 = Pre-test value in the non-experimental class,
O_4 = Post-test value in the non-experimental class,
X_1 = Treatment using the STEM approach,
X_2 = Treatment without using the STEM approach.

Then the normality test is calculated using the following Kolmogorov Smirnov formula (Razali & Wah, 2011).

ResultsandDiscussion

The results of the measurement of the average value of the pre-test and post-test results of students' critical thinking skills in the experimental class and non-experimental class can be seen in Table 2.

Table 2. Average pre-test and post-test results for the experimental class and the non-experimental class.

No	Aspect description	Experimental		Non-experimental	
		Pre-test	Post-test	Pre-test	Post-test
1	Number of students	29	29	30	30
2	Total value	1904.174	2000.08	1712.510	1837.511
3	Averages	65.661	68.965	57.084	61.250

Table 2 shows that the average post-test result of the experimental class's critical thinking skills after applying the STEM approach is greater than the average result of the non-experimental class pre-test. The determination of experimental and non-experimental classes is not based on high and low scores on pre test. But it determine those classes have the characteristics of students with the same age in learning needs and same level. In addition, this research focuses on how much the increase in the value given by the STEM approach to those who are not given the STEM approach in classroom learning. Furthermore, when it implements in the experimental class the average value becomes larger. It is clear that there is an increase in the value in both classes (experimental and non-experimental). Eventhough the range of non-experimental is higher than experimental value (post test - pre test), it doesn't mean that the non-experimental students have a good critical thinking skills than the student experimental class. In consequence of the beginning of starting values in pre test. In addition, it depends on actual situation that happened during the research field. If depicted in the graph, the average results of critical thinking skills are shown in Figure 1. The bar chart of the average pretest and posttest results for the experimental and non-experimental classes can be seen in Figure 1.

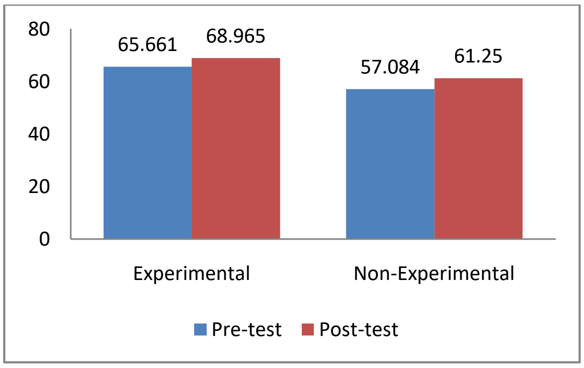


Figure 1. Bar chart of the average pre-test and post-test scores for the experimental and non-experimental classes.

Students who apply the STEM approach can form an awareness of STEM disciplines that create intellectual intelligence and human culture, so that what students learn at school is easier to absorb (Capraro et al., 2013). Meanwhile, students who did not receive the STEM approach were less able to construct their thoughts, especially in mathematics. This can be seen in the examples of students' answers in the experimental and non-experimental classes shown in Figures 2 and 3.

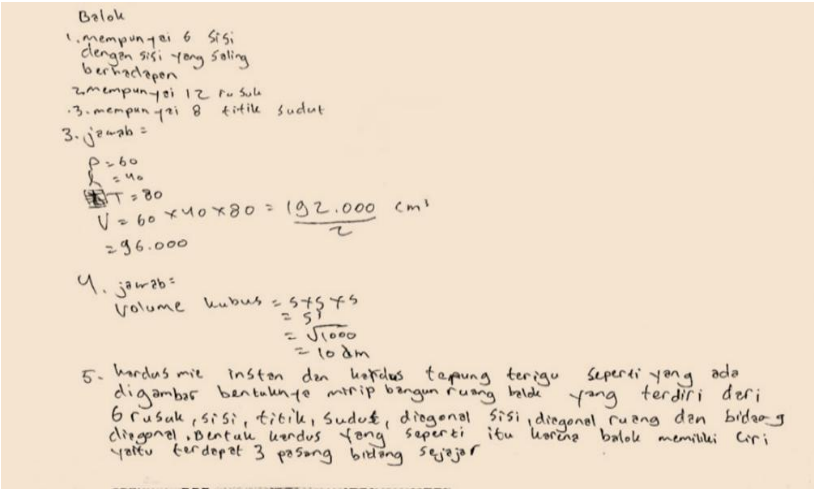


Figure 2. Examples of students' answers in the experimental class.

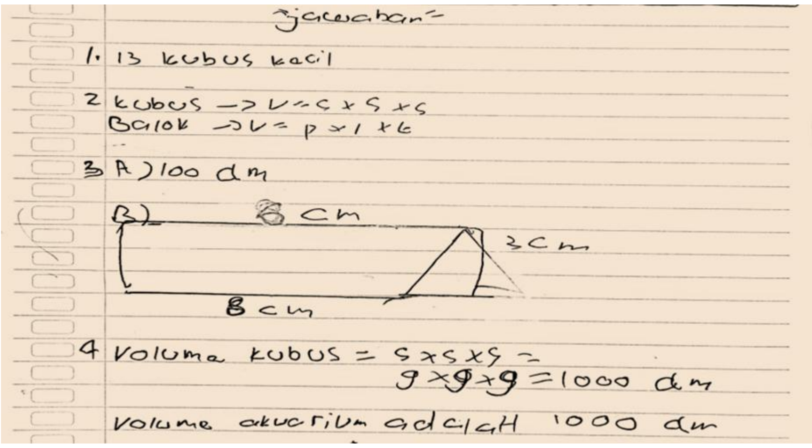


Figure 3. Examples of students' answers in the non-experimental class.

Based on the examples of students' answers between the experimental and non-experimental classes, there are differences, including (1) experimental class students are better at answering the questions given; (2) experimental class students gave detailed answers than the non-experimental class; and (3) experimental class students better understand the questions given than the non-experimental class. These differences indicate that the experimental class students meet the criteria for critical thinking skills. This is relevant to similar research on critical thinking skills by other researchers, namely (Afriana et al., 2016)and (Lestari, 2020).

Normality test is useful to find out whether a data is normally distributed or not. The data tested for normality consisted of initial and final data from the results of the experimental and non-experimental critical thinking skills. Normality test using *Kolmogorov Smirnov* with probability α = 0.05. The results of the analysis of the normality test on the pre-test data obtained a table value of 0.246. So that the largest|FT - FS|< table value (0.160 < 0.246) means that the pre-test data on critical thinking skills of the experimental class is normally distributed (see Table 3).

Table 3. The results of the normality test (pre-test) of critical thinking skills.

No	*Xi*	*F*	*F kum*	*Fs(x)*	*Mean*	*Deviasi Standar*	*Z*	*Ft(x)*	*Fs(x)-Ft(x)*	*|Fs(x)-Ft(x)|*
1	45.5	3	3	0.103	65.661	15.050	-1.339	0.090	0.013	0.013
2	55.5	8	11	0.379	65.661	15.050	-0.675	0.249	0.130	0.130
3	65.5	8	19	0.655	65.661	15.050	-0.012	0.495	0.160	0.160
4	75.5	5	24	0.827	65.661	15.050	0.653	0.743	0.084	0.084
5	85.5	3	27	0.931	65.661	15.050	1.318	0.906	0.025	0.025
6	95.5	2	29	1.000	65.661	15.050	1.982	0.976	0.024	0.024

The results of the analysis of the normality test to the post-test data obtained a table value of 0.246. So that the largest |*FT* - *FS*|<table value (0.111 < 0.246) means that the final observation data (post-test) of the experimental class's critical thinking skills is normally distributed (see Table 4).

Table 4. The results of the normality test (post-test) of critical thinking skills.

No	*Xi*	*F*	*F kum*	*Fs(x)*	*Mean*	*Deviasi Standar*	*Z*	*Ft(x)*	*Fs(x)-Ft(x)*	*|Fs(x)-Ft(x)|*
1	45.5	4	4	0.103	68.966	14.502	-1.618	0.052	0.085	0.085
2	55.5	3	7	0.379	68.966	14.502	-0.928	0.176	0.064	0.064
3	65.5	8	15	0.655	68.966	14.502	-0.239	0.405	0.111	0.111

4	75.5	7	22	0.827	68.966	14.502	0.450	0.673	0.084	0.084
5	85.5	5	27	0.931	68.966	14.502	1.140	0.872	0.058	0.058
6	95.5	2	29	1.000	68.966	14.502	1.829	0.966	0.033	0.033

Hypothesis testing is done by using r_{table}. If $r_{counts} > r_{table}$ with $\alpha = 0.05$ then Ha is accepted, and if $r_{counts} > r_{table}$ then Ha is rejected. It was found that r_{counts} 0.685 with N = 29 for = 0.05 obtained r_{table} 0.367; so that are $r_{counts} > r_{table}$ (0.685 > 0.367) and the hypothesis is accepted.

The average post-test score of students after applying learning with the STEM approach was higher than the pre-test score. The implementation of learning with a STEM approach can improve students' critical thinking skills in elementary schools and provide meaningful experiences for their lives in the future (Davidi et al., 2021). In addition, learning with the STEM approach taught in elementary schools can have a positive impact on children's development, one of which is the result of creativity by making various crafts as a result of learning the STEM approach in the form of a pencil box by applying the concept of building cubes and blocks as shown in Figure 4.

Figure 4. The results of students' work through STEM approach learning.

Through the STEM approach, students will automatically form a collaborative spirit and creativity in the learning process that integrates four disciplines of STEM to think critically and solve problems (Falentina et al., 2018). The benefits obtained by applying learning with the STEM approach in elementary schools are that it can support the skills of students in the 21st-century through the learning process, students are able to solve problems well, and can improve students' critical thinking skills through project-based digital literacy (Maula & Fatmawati, 2020).

The hallmark of learning with the STEM approach is that students are required to be actively involved in the learning process and require students to be able to integrate various STEM knowledge which then constructs their thinking so that they can think critically (Han et al., 2015; Sasmita & Hartoyo, 2020). The STEM approach needs to be taught through concrete and contextual things. Because the level of thinking elementary school age students has not been able to think abstractly. The four aspects of STEM in learning are able to improve critical thinking skills. The achievement of increasing critical thinking skills is due to a predetermined indicator. The indicator consists of six i.e., focus, reason, inference, situation, clarity, and overview (FRISCO) which is manifested in the form of pre-test and post-test questions. Where *F* (focus) is to introduce students to what should be discussed and identify problems. Furthermore, students need to provide rationally supporting reasons for the existing problems, this is part of the *R* (reason). *I* (inference) is the process of making conclusions based on appropriate arguments that investigated and evidence that has been obtained. *S* (situation) defined as belief in thinking process and making decision that supported by physical and social environment. Where *C* (clarity) is to convey the message to the decisions made. And the last indicator is *O* (overview) is to review and verify the problems that have been found previously. Those indicators are used to measure the extent of students' critical thinking skills and their resulting product with STEM approach as shown in Figure 4.

Students in the experimental class show higher pre test and post test scores, while the non-experimental class without STEM is actually growing but still lower in scores. Then the findings show that the STEM approach has been good associated to critical thinking skills. In addition, it has been proved that it can increase students' critical thinking skills as a part of 21st-century skills.

The STEM approach globally is a necessity and required by the world of education today, especially to increase students critical thinking skills of elementary schools. This approach direct students to involve, to motivated and to have a positive impact on their lives in acquiring knowledge since they are learning at a young age to support their future achievements (Lee et al., 2019; Taylor, 2018; Thibaut et al., 2018; Trúchly et al., 2019). Based on finding of this research and the results of a systematic review of the existing literature. This research is contributed to solve the learning problem in the 21st-century by implementing and providing a clear definition of the framework of the STEM approach in learning with the critical thinking skills of fifth grade elementary school students. The framework of this research has beneficial for learning implementation with student-oriented in elementary schools, which are the students become more active and innovative. However, further research is recommended to know the implementation of the STEM approach to other 21st-century skills i.e., creativity, collaboration, and problem solving.

The increase in students' critical thinking skills indicates the success of the application of the integrated project-based learning (PjBL) STEM approach. This needs to be maintained through a learning process in which educators must be able to foster students to work independently, creatively, innovatively against the various challenges of life. The STEM approach taught in schools provides a learning innovation for the world of education that aims to develop students' critical thinking patterns (Ulfa et al., 2019). Although there are some short comings in the implementation of learning, for example, educators are not familiar with the STEM approach. The advantages are that students are more enthusiastic about learning, active, and creative.

Conclusion

The skills to think critically has an important role to improve the way students thinking which aims to develop the perspective of collecting various information obtained during learning process. It is an essential need of every student in the 21st-century in order to achieve superior education. The problem that occurs today is the low critical thinking skills of students in elementary schools. The solution that can be made to improve students' critical thinking skills in elementary schools are implementing the STEM approach in learning. Because through the STEM in the classroom the learning become more active, creative, joyful, and meaningful.

In brief, this research concluded that the STEM approach in learning influence the critical thinking skills of fifth-grade students in Lampung Province. The results show that there is a significant effect between learning by the STEM approach on critical thinking skills, it prove that the average final result of critical thinking skills of students in the experimental class is greater than the non-experimental class. The experimental class (68.695) and the non-experimental class (61.250). The data analyze using Kolmogorov Smirnov with the largest $|FT\text{-}FS|$ t test < table value of 0.111 < 0.246. The students who have been given the STEM approach in learning more careful and detail in understanding and answering the questions than students who do not receive the STEM approach. The implication is the students critical thinking skills are increased by the STEM approach involved in learning.

Acknowledgements

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