Science, Technology, Engineering, and Mathematics (STEM) Approach to Improving Critical Thinking Skills Using the PBL Learning Model

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Abstract
The purpose of this study was to determine the effect of Science, Technology, Engineering, and Mathematics (STEM) approach to the improvement of critical thinking skills using PBL learning models. The population of the research is all of 10th graded IPA's students in SMA Negeri 7 Bandar Lampung which is 233 students. The selection of research sample uses a purposive sampling technique with the sample of class X IPA 5 was 31 students as the experimental class and class X IPA 6 was 30 students as the control class.The research design used Non-Equivalent Pretest Posttest Control Group Design. Data were tested by N-gain analysis, normality test, homogeneity test, Mann-Withney U Test and Effect size test. The results showed that there was an effect of the STEM approach to improving critical thinking skills as indicated by the Sig. (2-Tailed) is less than 0.05, 0.000, and the average value of N-gain (g) critical thinking skills in the experimental class is 0.73 (high category) and the control class is 0.56 (medium category). Effect size shows a value (d) of 1.49 included in high category. It can be concluded that the application of STEM approach using PBL learning models can improve students' critical thinking skills.

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1. Introduction

Learning in the 21st century requires various skills that must be mastered by students, so it is hoped that today's education can prepare students to master various skills. The US Based Partnership for 21st Century Skills (P21) identifies competencies needed in the 21st century, namely "The 4Cs" – communication, collaboration, critical thinking, and creativity. Assessment and teaching of 21st Century Skills (ATC21S) categorizes 21st century skills into 4 categories, namely way of thinking, way of working, tool for working and skill for living in the world (Griffin, McGaw, & Care, 2012). 21st century skills according to Wagner (2010) students are emphasized on critical thinking and problem-solving skills, agility and adaptability, and being able to communicate well. In the results of a study conducted by Wijaya, Sudjimat, & Nyoto, (2016) the indicators of critical thinking and problem solving have the highest value of 96.21%. This shows that critical thinking and problem-solving skills are very important for students to improve their skills and knowledge. Critical thinking is the ability possessed by individuals to develop knowledge, evaluate, and connect with facts or information from various sources to solve problems (Nurwahyuningsih, 2019). Critical thinking skills grow and develop in an environment that always generates curiosity. Critical thinking skills are the ability to analyze facts, trigger and organize ideas, defend opinions, make comparisons, draw conclusions, evaluate arguments and solve problems (Sugiyarti, et al., 2015). The existence of critical thinking skills will make it easier for

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students to solve problems because they will be able to analyze various ways and perspectives in solving problems.

The PBL learning model can overcome problems in physics learning because the PBL learning model is learning based on real problems in daily life that can improve students' critical thinking skills (Wulansari & Madlazim, 2019). In line with Downing's (2010) research, it is stated that PBL learning uses real-world problems for students to think critically and have problem-solving skills to acquire essential knowledge and concepts from the subject matter. According to Marra, et al., (2014) argue that the PBL learning model for students to learn in the context of solving authentic problems. PBL learning provides facilities for students to exchange opinions, analyze problems using various ways, and think about possibilities to solve a problem. Learning using the PBL learning model can increase learning activities, problem-solving skills, and develop good traits or character of students (Najib, Suyatna, & Wahyudi, 2017). The application of the PBL model in physics learning is less effective in explaining various complex problems. Therefore, it is necessary to combine with models or approaches to improve students' critical thinking skills. The most appropriate model or approach to achieve this goal is the STEM approach. Because in the STEM approach, many students are involved in a series of activities that develop their ability to solve problems.

STEM-based learning can develop if it is associated with the environment, so that a learning that presents the real world experienced by students in their daily lives (Widayanti, Abdurrahman, & Suyatna, 2019). STEM-based learning is one of the learning processes that can help students to achieve learning goals in the classroom (Bybee, 2013). STEM is a learning process that combines science , technology , engineering , and mathematics (Agnezi, Khair, & Yolanda, 2019). According to Kelley & Knowles, (2016) STEM learning is a learning approach that uses an interdisciplinary approach with active problem-based learning. The STEM learning process aims to improve students' creativity skills through the process of solving problems related to materials in daily life. The STEM approach helps students and teachers in solving problems in learning (Toto, 2019).

The application of STEM in learning activities consists of 4Cs so that students can find innovative solutions to problems faced in real life and can convey them well (Beers, 2011). The STEM learning approach by integrating its four components is able to produce useful mental activities to help bring out students' critical thinking which is characterized by the ability to solve problems, make decisions, analyze assumptions, evaluate, and conduct investigations (Khoiriyah, Abdurrahman, & Wahyudi 2018). Learning using the STEM approach is learning that requires students to develop the competencies they already have to be applied to be applied in solving problems in daily life related to technology and the surrounding environment. The knowledge process obtained from meaningful activities will become an understanding that is inherent in students' minds. The STEM integration program in learning is a learning program that combines two or more fields of science contained in STEM (Laboy Rush, 2010). STEM-based education is a learning education that can form Human Resources (HR) who are able to reason and think critically, logically, and systematically. STEM education encourages the development of skills in the field of STEM in dealing with problems in the real world (Asmuniv, 2015).

Based on preliminary research with interview methods that have been conducted by researchers with physics teachers at SMA Negeri 7 Bandarlampung explained that learning physics is quite difficult for students whose mathematical work is not thorough and in the learning process students are still reluctant to ask questions and there are many students

who tend to be less active in the learning process, so that many student learning outcomes have not reached KKM. Thus, it can be said that the empowerment of students' critical thinking skills at school has not been maximized and has not developed because in critical thinking skills students must be able to provide simple explanations, further explanations and be able to establish strategies and tactics. This research requires students to think critically and creatively to be able to solve these problems so that they can produce better solutions.

This research is supported by several previous research results. Sound wave learning with the STEM approach, students' critical thinking skills after applying the STEM learning approach showed that there was an increase in students' critical thinking skills (Khoiriyah, Abdurrahman, & Wahyudi, 2018). The application of LKS developed with the STEM approach can improve students' critical thinking skills (Lestari, Astuti, & Darsono, 2018). The application of the STEM integrated PBL model has a significant influence in providing learning innovations and has a positive impact on improving students' critical thinking skills (Ariyatun & Octavianeli, 2020). Learning using LKS with the use of STEM approaches that integrate aspects of science, technology, engineering, and mathematics can hone critical and creative thinking skills through questions that use indicators of critical and creative thinking skills (Yulianti et al., 2020). The effective use of PBL learning can be used as a powerful pedagogical approach to teach critical thinking skills while teaching domain knowledge as well as as as a powerful way to prepare students in today's difficult times for an increasingly digital future (Kek & Huijser, 2011).

This study aims to determine the influence of the influence of the Science, Technology, Engineering, and Mathematics (STEM) approach on improving critical thinking skills using the PBL learning model. Based on the description of the problem, the problem formulation of this study is how the influence of the Science, Technology, Engineering, and Mathematics (STEM) approach on improving critical thinking skills using the PBL learning model in grade X students of Newton's Law material on motion.

2. Method

This study is a study using the Quasi Eksperiment Design method with a Non-equivalent Control Group Design research design, namely one group of subjects is given treatment using the STEM approach with the PBL (experimental) learning model, while the other group is used as a control group using the conventional learning model. In this design, a pretest and posttest were carried out to determine the improvement of students' critical thinking skills. The population in this study is all students of class X SCIENCE SMA Negeri 7 Bandar Lampung in the second semester (even) of the 2019/2020 Academic Year which amounted to 7 classes with 233 students. The researcher used the purposive sampling technique to select control and experimental classes. This study has three forms of variables, namely free variables, bound variables, and moderator variables. The research instrument used is the Learning Implementation Plan (RPP), a test sheet consisting of 10 multiple-choice questions based on pretest and posttest to determine the improvement of students' critical thinking skills. The hypothesis test was carried out using the pretest and posttest result scores. The measurement of the improvement of students' critical thinking skills was carried out by measuring the N-gain obtained after students did the pretest and posttest in both classes. The data obtained from the N-gain class was then tested for normality and homogeneity. If the results of the N-gain data test are normal and

homogeneous, then an Independent Sample T-test is carried out. After conducting a hypothesis test using the Independent Sample T-test, if the data does not meet the requirements to be carried out using the Independent Sample T-test, it is carried out using the Mann-Whitney U Test, then the effectiveness test of using the STEM approach with the PBL defense model is carried out to improve critical thinking skills through the Effect size test.

3. Results

The research on *the Science, Technology, Engineering, and, Mathematics* (STEM) approach to improving critical thinking skills using the PBL learning model was carried out on January 13-27, 2020 at SMA Negeri 7 Bandarlampung, Bandar Lampung City. This study uses two classes, namely the experimental class and the control class which is carried out by providing *pretest* and *posttest* questions on critical thinking skills. The provision *of pretest* and *posttest questions* is carried out to measure students' skills before and after being given learning treatment. The implementation of learning in the experimental class was followed by 31 students (11 males and 20 females) and learning in the control class was followed by 30 students (11 males and 19 females). Based on the results of *the pretest* and *posttest, an* N-gain *test* was carried out which was used to determine the improvement of critical thinking skills. The improvement of students' critical thinking skills can be seen from the difference between the test results after and before being given treatment. The results *of the average* N-gain test *of the pretest* and *posttest* are shown in Table 1.

Table 1. Average Data *of N-gain* Students' Critical Thinking Skills

Score Acquisition	Eksperimen	Control
Highest Gain	0,87	0,86
Lowest Gain	0,62	0,30
Overnight gains	52,90	39,50
Average Score Increase	58%	44%
Rat-rata *n-gain*	0,73	0,56
Category Average *N-gain*	Height	Medium

Based on Table 1, it is known that in the experimental class, the average *N-gain* of students' critical thinking skills was obtained at 0.73 with the high category, while in the control class, the average *N-gain* of students' critical thinking skills was obtained at 0.56 with the medium category. Based on these results, it can be seen that the average *N-gain* of critical thinking skills improvement of students in the experimental class was higher than that of the control class. The data on the percentage of *N-gain* values of critical thinking skills in the experimental class and the control class is shown in Table 2.

Table 2. N-gain *Critical Thinking Skills* Category Data

Category	Experimental Classes		Control Class	
	Quantity	Percentages3	Quantity	Percentage
Height	22	70,97%	6	20%
Medium	9	29,03%	23	76,67%
Low	0	0,00%	1	3,33%

Based on Table 2, it is known that in the experimental class, the average *N-gain* of students' critical thinking skills was obtained by 0.73 in the high category where out of 31 students there were 22 students in the high category (70.97%), as many as 9 students were in the medium category (29.03%), and no students were in the low category. Meanwhile, in

the control class, the average *N-gain* was 0.56 in the medium category where out of 30 students there were 6 students in the high category (20%), as many as 23 students were in the medium category (76.67%), and as many as 1 student were in the low category (3.33%). The percentage of *N-gain* values with high criteria in the experimental class was greater than the percentage *of N-gain in the* control class. Meanwhile, the percentage increase with moderate criteria in the control class was greater than in the experimental class. The critical thinking skills data that have been obtained from the study were conducted normality tests and homogeneity tests. The results of the normality test data *of N-gain* values of critical thinking skills are shown in Table 3.

Table 3. Results of N-gain *Normality Test*

Parameter	Experimental Classes	Control Class
Asymp Sig (2-tailed)	0,607	0,557

Based on the data presented in Table 3, it can be seen that the *N-gain data* of the experimental class and the control class are normally distributed with *an Asymp Sig. (2-tailed)* value above 0.050, which is 0.607 for the experimental class and 0.557 for the control class. Based on the results of the test, it can be concluded that *the N-gain data of the* experimental class and the control class are normally distributed. After the normality test is carried out, the homogeneity test data is displayed in Table 4.

Table 4. Homogeneity Test Results

Levene Statistic	df1	df2	Say.
31,513	1	59	0,000

Based on Table 4, it can be seen that the results of the homogeneity test show that the value of sig is 0.000 or less than 0.05, so it can be concluded that the two classes have inhomogeneous variants. Based on the Normality and Homogeneity test, the data does not meet the Parametric test using *the Independent Sample T-test*, so a non-parametric test is carried out, namely using *the Mann-Whitney U Test* whether there is a difference in the value of N-gain of critical thinking skills between the experimental class and the control class in the study is statistically significant or significant. The results of *the Mann-Withney U Tets* test are shown in Table 5.

Table 5. Results of Data Hypothesis Test with *Mann-Withney U Test*
Critical Thinking Skills

Statisctical Test	*N-gain* Critical Thinking Skills
Mann-Withney U	155,500
Wilcoxon W	620,500
Z	-4,468
Asymp.Sig. (2-tailed)	,000

Based on Table 5, it can be seen that the hypothesis test from the experimental method using *the Mann-Withney U Test* produces *an Asymp Sig (2-tailed)* value or a significant value of 0.000, which is less than 0.05, then it can be concluded that H0 is rejected and H1 is accepted. Based on the results of the test, it can be concluded that there is a significant difference between the average critical thinking skills of students in the experimental class and the control class, so it can be concluded that there is an effect of the application of the STEM approach with the PBL learning model on the improvement of critical thinking skills of high school students. Furthermore, an effect size test was carried out. The *Effect size* test

is a step used to determine the effectiveness of the learning method or model that has been tested and applied to students. *The effect size* can be searched by getting the mean and *std. Deviation* from *the independent sample t-test* that has been carried out previously.

Table 6. Cohen's d Effect Size *Results*

Classes	*Mean*	*std. Deviation*	*Cohen's d*
Eksperimen	72,5977	5,22776	1,48815
Control	55,5635	15,32048	

Based on Table 6, it shows that the *mean* value for the experimental class is 72.5977 and *std. The deviation* is 5.22776 while the mean value of the *control class is 55.5635 and* std. The deviation *is 15.320448. When calculated with* an online effect size calculator , the results are obtained as shown in Figure 2.

Based on Figure 1, it shows that the calculation above produces *a Cohen's d* value of 1.48815 and *an effect-size r* of 0.5969. The provisions of the effect *size* table if the d value is above 0.8, then it can be categorized as large, then it can be concluded that the effectiveness of learning using the STEM approach with the PBL learning model is very effective in improving students' critical thinking skills because *the Coren's d* value obtained at *the effect size is high.* The test instrument used is a test sheet consisting of 10 multiple-choice questions based on relating STEM aspects in daily life and each question has different indicators of critical thinking skills. Each test instrument has problems related to Newton's Law such as objects placed on rough surfaces that are different from smooth surfaces, the relationship between mass and acceleration in the experiment, the force contained in the elevator and acceleration in the elevator, etc. Each student test instrument is required to find a concept and solve the given problem. The improvement of students' critical thinking skills can be seen from the increase in each indicator when given *pretest* and *posttest questions.* In general, the indicators of critical thinking skills in the experimental class and the control class have increased with different amounts of increase. The increase in the indicator of critical thinking skills in the experimental class is higher than in the control class. The improvement in critical thinking skill indicators in the experimental class can be seen in Figure 2 and the control class can be seen in Figure 3.

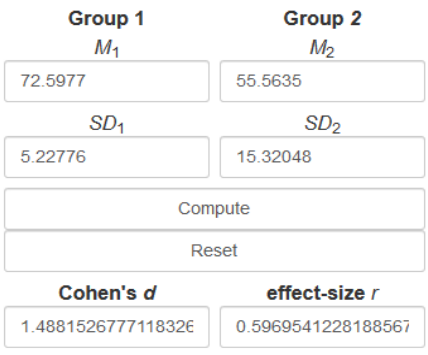


Figure 1. Effect *Size Calculation*

Based on Figure 2 and Figure 3, it shows that there is a significant difference in the indicators of critical thinking skills in the experimental class and the control class. The highest increase in indicators in the experimental class and the control class is in the indicator providing simple clarification and *the* indicator of building basic skills (*basic support*), but the increase in the experimental class is greater than in the control class. The

increase in this indicator is due to the increase in learning with a STEM approach using the PBL model, students are given the opportunity to play an active role in learning by providing a video or phenomenon and presenting authentic problems that require students to analyze, make hypotheses and solve problems with various strategies so that students can argue or argue.

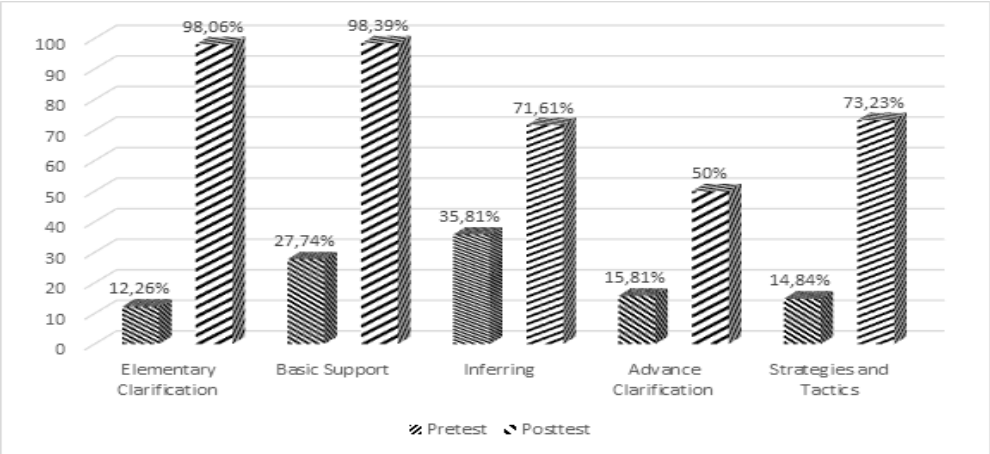


Figure 2. Experimental Class of Critical Thinking Skill Indicator Result

The lowest indicator increase in the experimental class and the control class was in the indicator providing *advance clarification*. This low increase occurred because students had not been optimal in the learning process, there were still students who did not understand the learning concept and were reluctant to ask questions and there were some students who still did not dare to express their opinions so that the improvement in skills provided further explanations for students in the low category. Indicators that are classified as good, respectively, are *inferring* indicators and strategies and *tactics*. The improvement in skills in the inferring indicator is quite good where after conducting demonstrations and experiments, students are required to be able to draw conclusions and provide explanations of the material that has been learned.

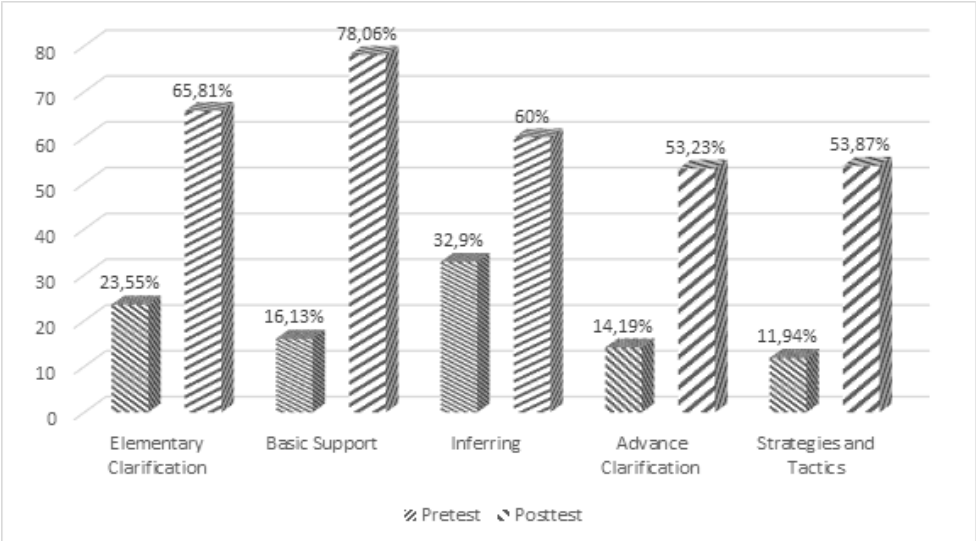


Figure 3. Control Class of Critical Thinking Skill Indicators Results

Student activities were observed by classroom teachers to see the achievement of students' critical thinking skills. The average daily Critical Thinking skill activity of students between the control class and the experimental class had differences that can be seen in figure 4 and figure 5. Based on figure 4 and figure 5, it shows that the average assessment of daily critical thinking skills indicators in the experimental class is 0.66 located at a medium level, then the average assessment of critical thinking skill indicators in the control class is 0.58 located at a medium level.

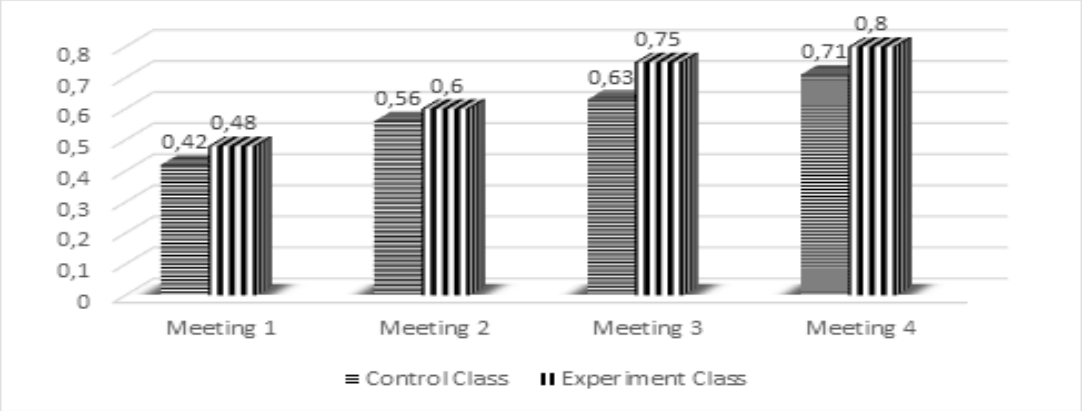


Figure 4. Critical Thinking Skills Indicator Assessment Chart Per Meeting

The learning process in the experimental class that applies the STEM approach with the PBL learning model is more effective and better in improving critical thinking skills compared to the control class, this happens because the learning in the experimental class is a combination of integration of aspects of the STEM approach syntax of the PBL learning model that focuses learning on students. Learning in experimental classes students are given problems that are often encountered in daily life, the problems given are such as when riding a vehicle that is initially stationary and then moves forward, our body will be pushed back, the paper under the glass glass is pulled quickly and the glass will remain still, Someone moving a light box will be faster than moving a heavy cupboard, and our hands when hitting the table will feel pain because the table provides a push force as a reaction to our hands then students are required to think critically and creatively in solving their problems, by integrating STEM aspects students can provide ideas or design and develop a technology that can be used to make it easier for students to solve problems so that students can think well and students can provide facts that support problem solving in daily life.

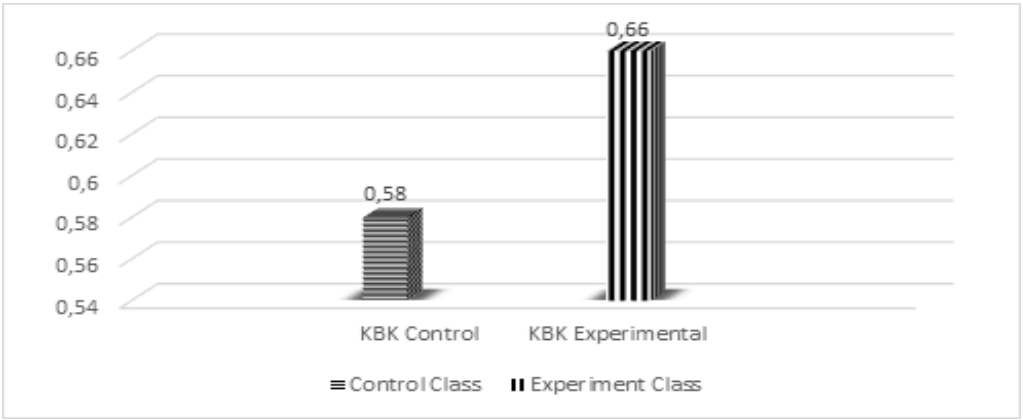


Figure 5. Graph of Average Assessment of Critical Thinking Skills Indicators Per Meeting

4. Discussion

The assessment results indicate that the scores for the experimental class were higher than those of the control class, although the difference was relatively small. This finding may be attributed to the implementation of a STEM approach integrated with Problem-Based Learning (PBL), which engages students in solving problems related to real-life situations and encourages the development of critical thinking skills. This explanation is consistent with Dalem, Nyeneng, and Suana (2017), who stated that PBL promotes student independence and self-confidence in problem-solving and decision-making within everyday contexts. Similarly, Amto, Ertikanto, and Nyeneng (2019) emphasized that critical thinking skills can be developed through activities that require students to analyze and observe problems systematically.

The integration of STEM and PBL also supports students' creativity and problem-solving abilities by connecting science, technology, engineering, and mathematics to authentic challenges. Winarni, Siti, and Supriyono (2016) explained that STEM-based PBL provides opportunities for students to develop creativity through the process of solving real-world problems. Furthermore, demonstrations and experiments allow students to strengthen their fundamental scientific skills and formulate conclusions based on their observations. These activities are consistent with the findings of Paramita et al. (2019), who highlighted the potential of STEM integration to create learning environments that facilitate argumentation. Likewise, Yilmaz et al. (2017) emphasized the central role of argumentation in science education, particularly in supporting meaning-making and enhancing learning outcomes.

The improvement in students' strategy and tactics skills can also be associated with their active involvement in experimental activities and technology design. In this study, students were challenged to solve problems through experiments and to design and construct a rubber-band-powered car as an application of Newton's Third Law of Motion. The process also involved analyzing the engineering principles underlying the technological product, enabling students to connect theoretical physics concepts with practical applications. This finding aligns with Widayanti (2013), who argued that active student participation can promote engagement throughout the learning process. Moreover, Mulyana, Abdurrahman, and Rosidin (2018) explained that engineering analysis activities help students understand how technological products operate as applications of physics concepts through various representations. Therefore, the combination of problem-solving, experimentation, and engineering design may contribute to the development of students' inference skills, as well as their ability to formulate strategies and make decisions.

At the beginning of the experimental class learning, daily phenomena related to the learning material are given, then students are required to prove the truth in these phenomena so that students can be trained to find out for themselves by thinking about how these phenomena can occur. Then students are given the opportunity to ask questions so that it can make it easier for students to find the facts that occur in the phenomenon. The phenomena given such as for example a ball rolling on slippery ice will continue to roll at a fixed speed and a burst of hot gas downwards produced by the combustion of rocket fuel will push the rocket to slide upwards. This opinion is in line with research conducted by Tiya Rahmawati (2019) explaining that the learning process using the PBL model students are required to discuss authentic problems, making students always empower critical thinking skills. Supported by research by White (2014) which states that the STEM

approach in learning seeks to produce students who have critical thinking skills, so that the students produced can become students who are able to provide creative solutions so that they will be able to compete in the world of work.

The learning process with a STEM approach students are guided to be more active and independent in finding answers to problems to the material that has been taught, this can improve students' critical thinking skills in learning. In line with the research conducted by Khoiriyah, Abdurrahman, & Wahyudi (2018) which states that active learning occurs if students become the center of learning, where with the implementation of the STEM approach students are required to find their own answers so that students will be actively involved in the learning process. The results of this study are also supported by research by Lou, et al. (2011) who stated that integrating STEM learning aspects makes students play a role as the center of learning process activities. This opinion is supported by Corlu, et al. (2014) who explain that STEM-based education has covered various scientific disciplines to gain comprehensive knowledge and is relevant to life as a form of preparation for producing students with a mindset that can provide various innovations.

The aspects of STEM consist of *science* as a process, concept, and procedure, *technology* as the application of science, *engineering* as science engineering, and *mathematics* as a tool. The syntax of the PBL learning model can spur students to be more active in learning, such as students are given the opportunity to develop their knowledge, give students the opportunity to think, search, find and explain examples of application of concepts that have been learned independently and confirm discussions with other friends and teachers play the role of facilitators and direct students if there are deviations or misconceptions. This opinion is supported by Satriani (2017) who states that the problem-based learning model (PBL) can improve critical thinking in the application of STEM approaches by providing (1) simple explanations, (2) building basic skills, (3) summarizing them, (4) providing further explanations, (5) arranging strategies and tactics.

In the aspect *of Science* as a process in learning Law I Newton shows a video of someone who is in a car then the car incubates suddenly and does a demonstration of Newton's Law I to find out the inertia of an object. Newton's Law II shows a video of a person moving a car by pushing the car and conductsan experiment on Newton's Law II to find out the relationship between acceleration with force and mass of objects using *PhET simulation* to determine the relationship between acceleration and mass and resultant forces acting on objects. Newton's Law III shows a video about the launch of a space rocket and demonstratesNewton's Law III by finding the principle of rocket propulsion in accordance with Newton's Law III using balloons. This process can improve critical thinking skills in providing simple explanations related to given phenomena, identifying or formulating a question and a given phenomenon and building basic skills by making hypotheses/temporary answers from given phenomena. In the aspect of *Science* as a concept, students are required to understand and explain Newton's Law I, Newton's Law II, and Newton's Law III as well as the application of the concepts of Newton's Law I, Newton's Law II, and Newton's Law III in daily life. In the Procedural *Science* aspect, students understand the stages of using *PhET simulation force and motion basic, force and motion, and the ramp* in Newton's Second Law experiment and theprocess of making *rubber band powered cars* as an application of Newton's Law III, this can improve students' critical thinking skills in applying strategies and tactics to decide an action to conduct demonstrations and experiments as well as determine the relationship between

acceleration with mass and resultant forces acting on objects through Newton's Second Law experiment.

The next stage in the aspect of *Technology* as the application of science in learning the application of technology from Newton's Law I is a seat belt that is used to avoid collisions between the driver and the front of the car or being thrown out of the car. The application of technology from Newton's Law II is a racing bike that is designed as light as possible so that it can go quickly. The use of PhET *simulation* on *force and motion basic, force and motion,* and *the ramp.* The application of technology from Newton's Law III which is best known in technological products is rockets and jet engines as well as the use of laptop and *mobile phone* technology in the learning process. In the aspect *of Technology* as the application of science, students are given "Technology and Applications of Physics" which aims to make it easier for students to understand technology related to the concept of inertial properties, Newton's Second Law, Newton's Law III, and objects moving in the inclined plane, frictional force, and cornering paths that are often encountered in daily life. This opinion is supported by research conducted by Asrizal et al. (2018) which states that STEM has a technological aspect that is closely related to the development of the current digital era. Technology users have the ability to access, find, and use a wide range of information contained in digital technology. The learning process with the STEM approach students can find out information about the application of technology related to the physics material studied.

At this stage, students begin to develop their critical thinking skills where students identify and provide hypotheses/temporary answers from the given phenomena, as well as determine the steps to be taken in solving the problem/phenomenon, providing further explanations of the results of demonstrations and experiments about Newton's Law I, Newton's Law II, and Newton's Law III in daily life, mprovide further explanation of the application of the concepts of Newton's Law I, Newton's Law II, and Newton's Law III in daily life, building basic skills by analyzing technology related to the application of Newton's Law I, Newton's Law II, and Newton's Law III. This is in line with the research conducted by Pratamawati, Prasetyo, & Satriana (2017) which states that in the learning process using the PBL learning model, students are required to actively develop their thinking skills to formulate problems and determine solutions in solving problems, so that they can develop their critical thinking skills.

The next lesson in the aspect of *Engineering* as a science engineering in learning Newton's Law I engineering used on seat belts is that if an accident occurs, the car experiences a large negative acceleration and quickly becomes stationary (stop). Inertia is the principle that underlies how a seat belt works. In an accident, the purpose of a seat belt is to hold passengers in place so that passengers avoid collisions with the front of the car or being thrown out of the car. In the study of Newton's Law II engineering used in racing bicycles, this bicycle is designed to be lightweight by being made using special materials that are very strong but very light such as carbon fiber. This makes the racer who rides this bicycle have high acceleration which is in accordance with Newton's Second Law that acceleration is inversely proportional to the mass of the object. In learning Newton's Law III theengineering used on the principle of rocket propulsion is that the rocket works on the force on the hot gas in a vertical downward direction (action) and according to Newton's Law III a reaction arises in the form of vertical upward thrust on the rocket worked by hot gas and designing the design of props for the application of Newton's Law III and Making *a Rubber Band Powered Car* as an application of Newton's Law III. At this stage, students begin

to develop their critical thinking skills where students can determine strategies and tactics in making *Rubber Band Powered Car* as an application of Newton's Law III, explain scientific engineering about the application of Newton's Law I, Newton's Law II, and Newton's Law III in daily life and analyze the application of the concepts of Newton's Law I, Newton's Law II, and Newton's Law III in daily life.

At this stage, students develop their thinking to be able to create an idea in solving problems in daily life with the physical concept of Newton's Law. In this study, students design and make a prototype, namely *Rubber Band Powerred Car* as a solution to problems and provide solutions to the limitations of energy sources. to provide students with provisions when related to technology development and utilizing energy sources as a countermeasure to the limitations of energy sources and developing environmentally friendly vehicles by utilizing wind energy sources or utilizing renewable energy. The making of Rubber Band Powerred Car *prototypes* in addition to the application of *the Engineering* aspect , this process can also improve students' critical thinking skills, where when students want to make prototypes, students first design ideas and develop the usefulness of technology. After the prototype is completed, which can then be used in the experiment, students can create various variables related to Newton's Law material on motion, such as friction, gravity and others. Engineering activities in the learning process such as creating projects in this study, namely making *a Rubber Band Powerred Car* that integrates science, technology, and mathematics also support to deepen students' knowledge and skills. In line with the statement of Cantrell, et al. (2006: 301-309) who stated that the integration of *engineering* aspects into learning materials can help students develop mastery of concepts and high-level thinking skills. Supported by the research of Pangesti, Yulianti, & Sugianto (2017) stated that learning associated with STEM aspects provides opportunities for students to understand physics concepts combined with technology, *engineering*, and mathematics through discussion activities, practicums, and project making.

The final stage in the aspect of *Mathematics* as a tool is that students are invited to model their own mathematical formulas in the material being studied, in this case encouraging students to carry out the process of critical thinking, so as to have an impact on improving good critical thinking skills where students can analyze the concepts of Newton's Law I, Newton's Law II, and Newton's Law III in equations and apply equations related to Newton's Law I, Newton's Law II, and Newton's Law III to solve problems in daily life. The mathematical aspect is integrated into four sub-concepts in the form of the use of number symbols for calculation and measurement. This can facilitate understanding and solving problems related to physics concepts. In this final stage, students are directed to formulate mathematical equations from the material that has been taught and find new knowledge and be able to solve the problem formulation given by the teacher so that from the learning process students can solve problems and create new ideas. This opinion is in line with the research conducted by Andawiyah (2014: 69-80), who stated that mathematics can make it easier to interpret something, so that it is easy to understand.

Students in the control class use the defense model that is commonly used by teachers in school. The learning process in the control class does not show the existence of engineering and technology aspects. Learning in the control class students are not given examples of technology that apply the physics concepts being studied and students are not required to analyze the engineering of the technology so that students are less able to improve their critical thinking skills. This will make students unaccustomed to solving

problems. In line with research conducted by Rahayuni (2016) states that learning that does not use applications (technology) in daily life, is less able to foster students' critical thinking skills.

The results of improving critical thinking skills in classes that apply the STEM approach with the PBL learning model are not optimal because some aspects of the STEM approach and the PBL learning model are suspected to have not been applied optimally during the learning process. Students are not used to learning using technology and engineering from the material learned. During the learning process, students are not optimal in engineering and creating a technology product because during the learning process students tend to feel rushed due to time limitations and there are still students who are reluctant to ask questions and opinions, this also has a bad impact because in learning there are no re-experiments that cause practicum errors and the results of the experiment are sometimes not in accordance with the theory. However, because confirmation discussions are held with other friends and students are given the opportunity to develop their knowledge and teachers play the role of facilitators and direct students if there are deviations or misconceptions, students' critical thinking skills can improve even though the time used is relatively short.

5. Conclusion

Based on the results of the research and discussion, it can be concluded that: There was a significant increase in the critical thinking skills of class X students in Newton's Law material on motion in learning using the STEM approach with the PBL learning model which was shown by the average N-gain value in the experimental class of 0.73, while in the control class using conventional learning with a scientific approach had an average value of 0.56. Learning the STEM approach using the PBL model was very effective in improving critical thinking skills as shown by the results of the effect size test resulting in a Cohen's d of 1.48815 with a high category. Students were given daily life problems in learning so that they could grow students' critical thinking skills which were solved by integrating STEM aspects. Learning using the STEM approach and the PBL learning model can improve students' critical thinking skills well because the learning process is centered on students who are required to think independently in solving problems in daily life.

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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