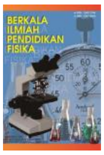

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The Effect of Science, Technology, Engineering, and Mathematics (STEM) Approaches on Critical Thinking Skills Using PBL Learning Models

I Putu Yogi Setia Permana, I Dewa Putu Nyeneng, and I Wayan Distrik
Physics Education Study Program, Teacher Training and Education Faculty
Universitas Lampung, Indonesia
Putu07558@gmail.com

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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 Problem Based Learning (PBL) models. The population of the research was all of the 10th grade IPA students in SMA Negeri 7 Bandar Lampung which were 233 students. The selection of research sample used a purposive sampling technique with the sample of class X IPA 5 that consisted of 31 students as the experimental group and the class X IPA 6, which was 30 students, as the control group. 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 Effect size test. The results showed that there was a significant effect of the STEM approach in improving critical thinking skills as indicated by the Sig. (2-Tailed), which was less than 0.05, 0.000, and the average value of N-gain (g) critical thinking skills in the experimental class was 0.73 (high category) while the control class was 0.56 (medium category). Effect size showed a value (d) of 1.49 included in high category. It can be concluded that the application of STEM approach using PBL learning model can improve students critical thinking skills. Implications of the study are discussed. The use of the STEM approach using PBL learning model can be used as an alternative for teachers as an effort to improve students' critical thinking skills.

Keywords: Critical thinking skills; Problem Based Learning (PBL); STEM approach

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INTRODUCTION

Learning in the 21st century demands a variety of skills that students must master, so that it is hoped that education can prepare students to master various skills. The United States (US) Based Partnership for 21st Century Skills (P21) identifies the 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 four categories, namely ways of thinking, ways of working, tools for work and skills for living in the world (Griffin, McGaw, & Care, 2012). The 21st century skills refer to students who are interested in critical thinking skills and master problems, dexterity and adaptability, and are able to communicate well (Wagner, 2010).

In a relavant study, indicators of critical thinking and solving problems have the greatest value of 96.21% (Wijaya, Sudjimat, & Nyoto, 2016). This shows that critical thinking skills and problem solving 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. Critical thinking skills grow and develop an environment that always creates curiosity. Critical thinking skills are the ability to analyze facts, generate and organize ideas, defend opinions, make comparisons, draw conclusions, evaluate arguments and solve problems (Widha, Aminah, & Nonoh, 2015). The existence of critical thinking skills will make it easier for students to solve problems because they will be able to analyze various ways and perspectives in solving problems.

Problem Based Learning (PBL) model is a learning model based on problems that exist in real life and daily life so that this is expected to help improving students' critical thinking ability (Wulansari & Madlazim, 2019). PBL learning uses real-world problems for students to think critically and own problem solving skills to obtain essential knowledge and concepts from the subject matter (Downing, 2010). In addition, the study that has been done by Igut et al where the PBL model was used for learning topics about temperature, seeding and heat which of course had the aim to improve students' critical thinking ability and increase motivation was proven successful (Igut, Ain, & Pratiwi, 2019).

STEM based learning can develop if it is related to the environment, so that it can create learning that presents the real world that students experience in everyday life (Widayanti, Abdurrahman, & Suyatna, 2019). Helping students achieve their learning goals can be taught with STEM-based learning (ByBee, 2013). STEM is a learning process that combines science, technology, engineering, and mathematics (Agnezi, Khair, & Yolanda, 2019). STEM learning is a learning approach that uses an interdisciplinary approach with problem-based active learning (Kelley, 2016). The STEM learning process aims to improve students' creative abilities through a problem-solving process related to material in everyday life. The STEM approach helps students and teachers to solve problems in learning (Toto, 2019).

Based on preliminary research with interview methods that have been conducted by researchers with physics subject teachers at SMA Negeri 7 Bandarlampung in 2019, it was explained that learning physics was considered quite difficult for students whose mathematics works were not thorough; while in the learning process, there were still many students who were reluctant to ask questions and tended to be less active in learning activities so that it had an impact on student learning outcomes which have not reached the minimum completeness criteria. So that from these problems, the critical thinking skills of students in schools have not been maximized and developed because of their critical thinking skills. From these problems, researchers are guided to be able to solve these problems so that they can produce better solutions.

This research is supported by several previous research results. One of which is the research about learning sound waves using the STEM approach, where the result of the research conducted was that there was an increase in students' critical thinking ability when applied STEAM-based approach (Khoiriyah, Abdurrahman, & Wahyudi, 2018). The application of student worksheets developed with the STEM approach can improve students' critical thinking skills. The application of the PBL model combined with STEAM has the effect of influence in providing learning innovation and positive influences where students' critical thinking ability is increased (Ariyatun & F, 2020). Learning using worksheets using the STEM approach that integrates 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, Wiyanto, Rusilowati, & Nugroho, 2020).

This study aims to determine the effect of the Science, Technology, Engineering, and Mathematics (STEM) in enhancing students' critical thinking skills by using PBL learning models. So, the problem in this study is how stem approach influences the improvement of critical thinking skills by using PBL model in grade X students with Newton's Law material about motion.

METHOD

This study used the Quasi Experiment Design method with a Non-equivalent Control Group Design research design, where one group of the subjects was treated with the STEM approach with the PBL learning model (experimental group), while another group was used as a control group using the conventional learning model (commonly used learning by school teachers). In this study, a pretest and posttest were conducted to determine the improvement of students' critical thinking skills. The population of this study was all students of class X IPA SMA Negeri 7 Bandar Lampung in the second semester (even) of the 2019/2020 academic year, totaling 7 classes with 233 students. Researchers used the purposive sampling technique to select the control and experimental groups. Selection of research samples was done by looking at the learning outcomes of all classes then selected according to the objectives of the research and those with almost the same abilities. The sample in this study were 31 students of class X IPA 5 as the experimental class and 30 students of class X IPA 6 as the control class. This study used three forms of variables, namely the independent variable, the dependent variable, and the moderator variable. The independent variable of this study was the STEM approach. The dependent variable was critical thinking skills. The moderator variable was the Problem Based Learning (PBL) learning model. Data retrieval conducted in this study included research instruments, observation results and student learning assessment results. The research instrument used was the Learning Implementation Plan (RPP), a test sheet consisting of 10 multiple choice questions with pretest and posttest reasons to determine the increase in students' critical thinking skills. In developing the instruments used in this study, preliminary research was carried out to determine the characteristics of students and adjust learning models and approaches that would be effective for use in improving students' critical thinking skills. Before the instrument was used in the study, the instrument was tested first using the validity test and the reliability test using the SPSS version 21.0 program. The data obtained was then tested by analyzing the research data and testing the hypothesis to determine whether the research hypothesis was accepted or rejected. Hypothesis testing was done using the pretest and posttest results.

The N-gain test was used to determine the improvement of students' critical thinking ability. N-gain data was derived from the pretest and posttest values of both classes. After that, Independent Sample T-Test was conducted and independent sample T-test using Mann-Whitney U test and effectiveness test of STEM approach combined with PBL model to improve critical thinking ability.

The STEM approach used in this experimental research was an integrated STEM approach. The integrated STEM approach is an approach that combines four STEM disciplines in one learning subject (Breiner, Harkness, Johnson, & Koehler, 2012; Sanders, 2009). In my research, the implemented STEM approach integrated four disciplines, namely science, technology, engineering and mathematics applied in real world context that can make students active, collaborative, critical thinking, skillful, and meaningful learning. The syntax of the Problem Based Learning (PBL) learning model is to provide orientation about the problem to students, organize students to research, help investigate independently or in groups, develop and present work results, and analyze and evaluate the process of overcoming problems (Sugiyanto, 2009). Aspects of critical thinking skills are assessed using aspects, namely providing simple explanations (elementary clarification), building basic skills (basic support), concluding (infer-ring) providing further explanations (ad-vance clarification) and strategies and tactics (strategies and tactics) (Ennis, 2011).

Learning using the STEM approach with a problem-based learning model begins with giving a pretest to measure students' initial abilities, the learning is carried out in accordance with the learning implementation plan with 5 learning stages where the problem-based learning model and integrated STEM approach. Starting from the stage of giving ideas about the problem, organizing students to do research, helping to investigate independently or in groups and conducting analysis and evaluation of the problem-solving process. After all the stages are completed, measuring students' critical thinking skills based on learning is done with the STEM approach with a problem-based learning model.

RESULT AND DISCUSSION

In this section will be presented results and discussion in this research which was conducted to see the effect of the Science approach, Technology, Engineering, and Mathematic (STEM) towards improvement of critical thinking skills using PBL learning model in students class X material about Newton's Law. This research was conducted by providing questions of the pretest and posttest containing critical thinking skills criteria.

The test instrument used was a test sheet consisting of 10 reasoned multiple choice questions by linking STEM aspects in everyday life and each question had different indicators of critical thinking skills. Each test instrument had problems related to Newton's Law such as objects placed on a rough surface are different from a smooth surface, the relationship between mass and acceleration in the experiment, the force in the lift and the acceleration in the lift, etc. Each student test instrument was required to find concepts and solutions to the problems given. The improvement of students' critical thinking skills can be seen from the improvement of each indicator in given the pretest and posttest questions. In general, the indicators of critical thinking skills in the experimental class and control class have increased with different amounts of improvement. To see more clearly the improvement of each indicator of critical thinking can be seen in Figure 1 and Figure 2.

Based on Figure 1 and Figure 2 it can be seen that there was a significant difference between the indicators of critical thinking skills between the two classes. The highest increase in indicators was in the experimental class in which the increase in the experimental class was greater than the control. To find out how much influence of learning with the STEM approach using the PBL model can be seen from the research results as follows:

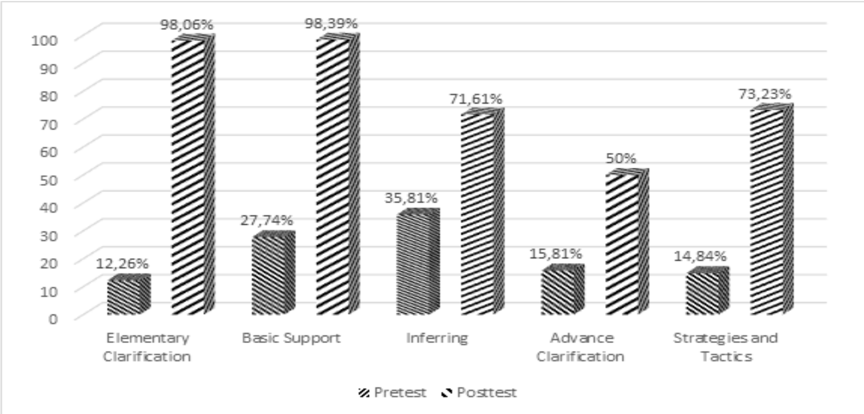

Figure 1 Graph of Average Achievement Indicators for Critical Thinking Skills Experiment Class Based on Pretest and Posttest Results

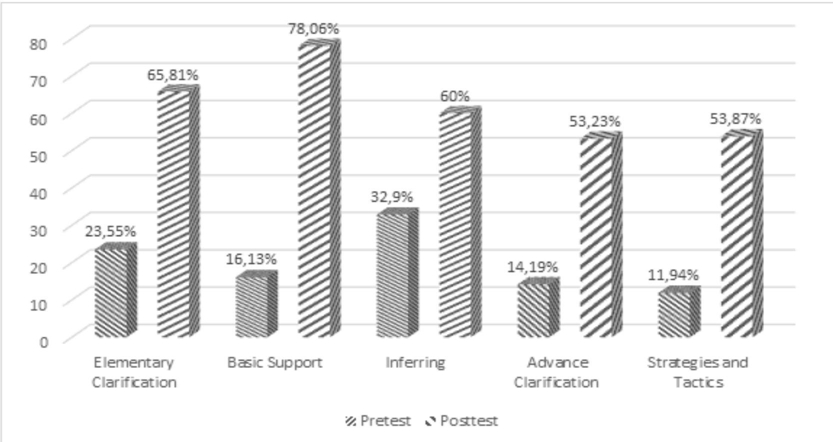

Figure 2 Graph of Average Achievement of Indicators of Critical Thinking Skills for the Control Class Based on the Results of the Pretest and Posttest

N-gain Critical Thinking Skills

The increase in students' critical thinking skills can be seen from the average results of the pretest and posttest N-gain test shown in Table 1.

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

Score Acquisition	Experi-ment	Control
Highest Gain	0.87	0.86
Lowest Gain	0.62	0.30
Average Gain	52.90	39.50
Increase in Average Score	58.00%	44.00%
-gain average	0.73	0.56
Category N-gain average	High	Medium

Based on Table 1, it can be seen that the average N-gain increase in critical thinking skills of experimental class students is higher than the control class. The data for the category of the percentage of the N-gain value of critical thinking skills in the experimental class and the control class are shown in Table 2.

Table 2 Data on N-gain Categories of Critical Thinking Skills

Category	Experiment Class		Control Class	
	Amount	**Percentage**	**Amount**	**Percentage**
High	22	70.97%	6	20.00%
Medium	9	29.03%	23	76.67%
Low	0	0.00%	1	3.33%

Based on Table 2, it is known that the experimental class obtained an average N-gain of students' critical thinking skills of 0.73 in the high category and had a percentage of the N-gain value with high criteria which was greater than the N-gain percentage in the control class. Meanwhile, the percentage increases with moderate criteria in the control class which is greater than the experimental class.

Critical thinking skills data obtained from the study were carried out by using the normality test and homogeneity test. The results of the normality test of the N-gain value for critical thinking skills are presented in Table 3.

Table 3 N-gain Normality Test Results

Parameter	Experiment Class	Control Class
Asymp Sig (2-tailed)	0.60	0.56

Based on the data presented in Table 3, it can be seen that the N-gain data for the experimental class and control class are normally distributed, with the Asymp Sig. (2-tailed) 0.60 for the experimental class and 0.56 for the control class.

Homogeneity Test Results

After the normality test is carried out the homogeneity test, the homogeneity test data shown in Table 4.

Table 4 Homogeneity Test Results

Levene Statistic	df1	df2	Sig.
31.51	1	59	0.000

Based on Table 4, it can be seen that the two classes have non-homogeneous variants. So, a non-parametric test was carried out using the Mann-Whitney U Test to see whether there was a difference in the N-gain value of critical thinking skills between the experimental class and the control class in the study. The results of the Mann-Withney U Tets test are shown in Table 5.

Table 5 Data Hypothesis Test Results with the Mann-Withney U Test Critical Thinking Skills

	N-gain **Critical Thinking Skills**
Mann-Withney U	155.50
Wilcoxon W	620.50
Z	-4.47
Asymp.Sig. (2-tailed)	0.00

Based on Table 5, it can be seen that H_0 is rejected and H_1 is accepted. From these results, there was a significant difference between the average critical thinking ability of students in the experimental class and the control class, so it can be concluded that there was an effect of the learning implementation with STEM approach with the PBL learning model in improving the critical thinking skills of high school students.

Securities Size Calculation

The effect size test was used to determine the effectiveness of learning methods or models that have been tested and applied to students.

Table 6 Cohen's d Effect Size

Class	*Mean*	*Std.Devia-tion*	*Cohen's d*
Experi-ment	72.59	5.22	1.49
control	55.56	15.32	

Based on Table 6, it can be seen that the average value for the experimental class is greater than the control class. To be more accurate, it was recalculated using an online effect size calculator, the results are shown in Figure 1.

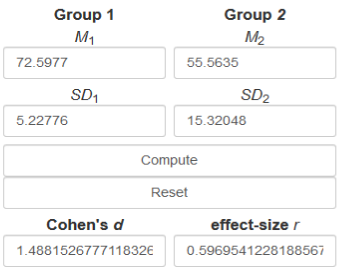

Figure 3 Effect Size Calculation

Based on Figure 3, it can be seen that the above calculation produces a Cohen's d value of 1.48815=1.49 and an effect-size r of 0.5969. The provisions of the effect size table if the value of d is above 0.8 then it can be categorized as large, so that the effectiveness of learning using the STEM approach with the PBL learning model is very effective in improving students' critical abilities.

Critical thinking skills

The increase in this indicator is because in learning with the 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 present authentic problems that require students to analyze, make hypotheses and solve problems with various strategies so that students can argue. Students are given the opportunity to conduct demonstrations and experiments in learning so that they can build students' basic skills, then students are able to draw conclusions from the demonstrations and experiments carried out. This opinion is in line with the research of Paramita et al., (2019) which stated that the integration of the STEM approach in the application of learning strategies was able to provide content that provided an area for argumentation so that argumentation skills in learning could be trained. This opinion is also supported by relevant study whose argumentation was centered in science education to make meaning and have an important effect on learning (Yilmaz, Cakiroglu, Ertepinar, & Erduran, 2017).

The lowest increase in indicators in the experimental class and control class was the indicator of providing further explanation (advance clarification). This low increase occured because students had not been maximal in the learning process. There were still students who did not understand the concept of learning and were reluctant to ask questions. Also, there were some students who still did not have the courage to express their opinions so that the skills increase in providing further explanations for students was in the low category. Indicators that were classified as good, respectively, were inferring indicators and strategies and tactics.

Skills improvement on indicators was concluded well enough in which after conducting demonstrations and experiments students were required to be able to draw conclusions and provide explanations of the material that has been studied. The improvement of students' strategic and tactical skills was quite good because students were given problems that must be solved by conducting experiments and also involved in designing and making prototype technology products for the Rubber Band Powerred Car as the application of Newton's Third Law and analyzing the engineering of a technology that helped students to be able to understand physics firsthand. This is in line with research (Widayanti et al., 2019) which stated that student involvement in the learning process could encourage student activity during the learning process. Therefore, the skills with the indicators of concluding and the strategy and tactics can improve properly. It can be added that engineering design activities of a technology requires students to explain how technology works as the application of physics concepts using various representations such as X, Y and T .

Student activities were observed by the class teacher to see the achievement of students' critical thinking skills. The average activity of students' daily Critical Thinking skills between the control class and the experimental class has a difference, it can be seen in Figure 4 and Figure 5.

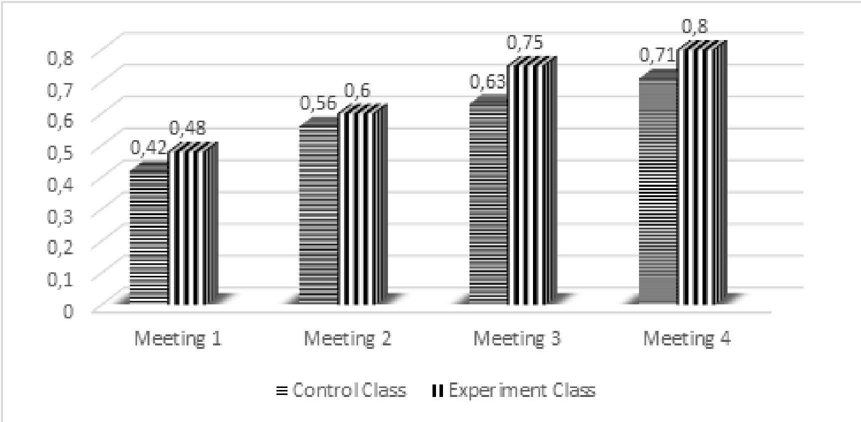

Figure 4 Graph of Critical Thinking Skills Assessment Indicators per Meeting

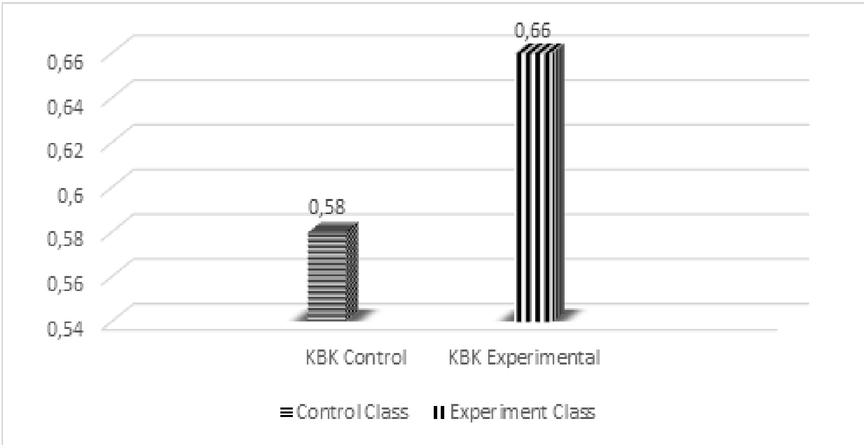

Figure 5 Graph of Average Evaluation of Critical Thinking Skills Indicators per Meeting

Based on Figure 4 and Figure 5, it shows that the average assessment of the assessment indicators in the experimental class looks bigger but not so different from the control class because students in the experimental class used the STEM approach with the PBL learning model where students were required to solve problems in everyday life so that students could improve their critical thinking skills. This opinion is supported by relevant study which explained that problem-based learning models can teach students to develop independence and confidence in solving problems and making decisions in the context of everyday life (Dalem, Nyeneng, & Suana, 2017). Students' critical thinking skills will be trained and emerge if students are trained in solving problems by analyzing and paying attention to a problem given to students (Amto, Ertikanto, & Nyeneng, 2019).

The learning process in the experimental class was more effective and better in increasing critical thinking skills than the control class. This happens because learning in the experimental class has a combination of integrated aspects of the STEM approach with the PBL learning syntax model that focuses on student learning. In the experimental class, students were given problems that are often encountered in everyday life, the problems given include things such as when driving a vehicle that is initially idle then moving forward, our bodies will be pushed backwards; the paper under the glass is pulled quickly and the glass will remain still; moving the light box will move the heavy cupboard faster; and our hands when hitting the table will hurt because the table gives encouragement as our hand reacts, so students were required to think critically and creatively in solving their problems by assessing STEM.

Aspects of students provide ideas or design and develop a technology can be used to facilitate students in solving problems so that students can think well and provide facts that support problem solving in everyday life. This opinion is shared with the relevant study which explains that the PBL model with a STEM approach is a learning that is integrated with science, technology, engineering, and mathematics to foster students' criticality and creativity through problem processes in everyday life (Winarni, Z, & Supriyono, 2016).

At the beginning of learning, the experimental class was given daily phenomena related to the learning material, then students were required to prove the truth of this phenomenon so that students could be trained to find out for themselves by thinking about how this phenomenon could occur. Then, students were given the opportunity to ask questions so that it would make it easier for students to find facts that occur in this phenomenon. Certain phenomena used as an example such as a ball rolling on slippery ice will continue to roll at a constant speed. This opinion is in line with research which explains that in the learning process using the PBL model students are required to discuss authentic problems, so that students always empower critical thinking skills (Rahmawati, 2019). STEM approach in learning seeks to produce students who have critical thinking skills, so that the students can be able to provide creative solutions so that they can compete in the working field (White, 2014).

When carrying out the learning process using the STEM approach, students will be guided to be more active and independent in finding answers to the material problems given, this aims to improve students' critical thinking skills in learning activities. This is also in line with research which states that active learning occurs when students become learning centers, in which by applying the STEM approach students are required to find their own answers and be actively involved in the learning process (Khoiriyah et al., 2018). The results of this study are also supported by relevant study which states that integrating aspects of STEM learning makes students play a role as the center of the learning process activities (Lou, Chou, Shih, & Chung, 2017). STEM-based education has covered various disciplines to obtain comprehensive and life-relevant knowledge as a form of preparation to produce students with a mindset that can provide various innovations (Corlu, 2014).

The STEM aspects consist of science as a process, concept and procedural, technology as an application of science, engineering as an engineering science, 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, think, search, find, and explain examples of concepts application that have been learned independently, and also confirm discussions with other friends. The role of the teacher as a facilitator directs students if there are deviations or misconceptions. Problem-based learning model (PBL) can improve critical thinking in the application of the STEM approach by (1) providing simple explanations, (2) building basic skills, (3) drawing conclusions, (4) Providing further explanation, (5) Setting strategy and tactics (Satriani, 2017).

In the aspect of Science, as a process in learning Newton's First Law, it shows a video of someone who is in a car then the car suddenly cramps and demonstrates Newton's First Law to determine the inertia of objects. Newton's Second Law shows a video of a person moving a car by pushing the car and carrying out Newton's Second Law experiments to find out the relationship between acceleration and the force and mass of the object using the PhET simulation to determine the relationship between acceleration and mass and the resultant force acting on it. Newton's Third Law shows a video about launching a rocket to the sky and demonstrates Newton's Third Law by discovering the principle of propelling a rocket in accordance with Newton's Third Law using a balloon. This process can improve critical thinking skills in providing simple explanations related to a given phenomenon, identifying or formulating a given question and phenomenon, and building basic skills by making hypotheses/temporary answers from the given phenomena. In the aspect of Science as a concept, students are required to understand and explain Newton's First Law, Newton's Second Law, and Newton's Third Law and the application of Newton's First Law, Newton's Second Law, and Newton's Third Law in everyday life. In the Science Procedural aspect, students understand the stages of using the PhET simulation of force and motion basic, force and motion, and the ramp in Newton's Law II experiment and the stages of making a rubber band powered car as the application of Newton's Third Law. This can improve students' critical thinking skills in applying strategy and tactics and deciding an action to perform demonstrations and experiments and determining the relationship between acceleration and mass and the resultant force acting on the object through Newton's Second Law experiments.

The next stage is in the aspect of Technology as the application of science in learning the application of technology from Newton's First Law, which is the seat belt 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 Second Law is a racing bicycle that is designed to be as light as possible so that it can go fast. PhET simulation is used on force and motion basic, force and motion, and the ramp. The application of technology from Newton's Third Law, which is best known in technology products, is rockets and jet engines and also the use of laptop and cellphone 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 rela-ted to the concept of inertia, Newton's Second Law, Newton's Third Law, and objects moving on an inclined plane, friction force, and cornering roads that are often encountered in everyday life. STEM has technological aspects that are closely related to the development of the current digital era (Asrizal & Dewi, 2018). Technology users have the ability to access, find, and use a wide variety of information contained in digital technology.

At this stage students begin to develop critical thinking skills where students identify and provide hypotheses /temporary answers to the phenomena that have been given, and determine the steps to be carried out in solving problems / phenomena, providing further explanations of the results of demonstrations and experiments on Newton's First Law, Newton's Second Law, and Newton's Third Law in everyday life, provide further explanations about the application of the concepts of Newton's First Law, Newton's Second Law, and Newton's Third Law in everyday life, building basic skills by analyzing technology related to the application of the Law Newton's I, Newton's Second Law, and Newton's Third Law. 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 critical thinking skills (Pratamawati, Prasetyo, & Satriana, 2017).

The next lesson in the engineering aspect of engineering science in learning Newton's First Law of engineering used on seat belts is that if an accident occurs, the car experiences a large negative acceleration and quickly becomes idle (stops). Inertia is the principle that underlies the workings of a seat belt. In an accident, the purpose of the seat belt is to hold the passenger in place so that the passenger avoids colliding with the front of the car or being thrown out of the car. In Newton's second law lesson, the engineering used on racing bikes is that these bikes are designed lightly and are made using a special material that is very strong but very light like carbon fiber. This is what makes the racer who rides this bicycle have a high acceleration which is in accordance with Newton's Second Law that acceleration is inversely proportional to the mass of the object. In the study of Newton's Law III, the engineering used in the principle of propelling a rocket is that the rocket exerts a force on hot gas in a vertical downward direction (action) and according to Newton's Third Law there is a reaction in the form of an upward vertical thrust on the rocket which is done by hot gas and designing a design props for the application of Newton's Third Law and Making a Rubber Band Powered Car as an application of Newton's Third Law. At this stage students begin to develop critical thinking skills where students can determine strategies and tactics in making Rubber Band Powered Car as the application of Newton's Third Law, explaining scientific engineering about the application of Newton's First Law, Newton's Second Law, and Newton's Third Law in everyday life. and analyze the application of Newton's first, second and third law concepts in everyday life.

At this stage students develop their thinking to be able to create ideas in solving problems in everyday life with the concept of Newton's Law of physics. In this study, students designed and made a prototype, namely the Rubber Band Powered Car as a solution to problems and provide solutions to limited energy sources. It aims to provide provisions for students when it comes to technology development and the use of energy sources to overcome limited energy source and develop environmentally friendly vehicles by utilizing wind energy sources or utilizing renewable energy. Making a prototype of a Powered Car Rubber Band apart from being an application of the engineering aspects of this process can also improve students' critical thinking skills, in which everytime students want to make a prototype, they first design ideas and develop the usefulness of technology. After the prototype has been made, then it can be used in experiments, students can create various variables related to Newton's Law of motion, such as friction, gravity and others. Engineering activities in the learning process such as making a project in this study, namely making a Rubber Band Powered Car that is integrated with science, technology, and mathematics, also supports the deepening of students' knowledge and skills. The integration of engineering aspects into learning materials can help students develop mastery of concepts and higher-order thinking skills (Cantrell, Pekcan, Itani, & Bryant, 2006). Learning related to STEM aspects provides opportunities for students to understand physics concepts combined with technology, engineering, and mathematics through discussion activities, practicum, and project creation (Pangesti, Yulianti, & Sugianto, 2017).

The final stage in the aspect of mathematics as a tool, namely students are invited to model the mathematical formulas themselves in the material being studied, in this case it encourages students to carry out critical thinking processes, so that it has an impact on improving good critical thinking skills where students can analyze Newton's First Law concepts , Newton's Second Law, and Newton's Third Law in equations and apply equations related to Newton's First Law, Newton's Second Law, and Newton's Third Law to solve problems in everyday life. Mathematical aspects are integrated into four sub-concepts in the form of using number symbols for calculation and measure-ment. 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 can solve the problem formulation given by the teacher so that from the learning process students can solve problems and create new ideas. The mathematics can make it easier to interpret something, so that it is easy to understand (Andawiyah, 2014).

Students in the control class use the learning model commonly used by teachers in school. The learning process in the control class did not show any engineering and technological aspects. Learning in the control class students are not given examples of technology that apply the concepts of physics being studied and students are not required to analyze the engineering of the techno-logy so that students are less able to improve their critical thinking skills. This will make students unaccustomed to solving problems. Learning that does not use applications (technology) in everyday life is less able to foster students' critical thinking skills (Rahayuni, 2016).

The results of increasing 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 have not been optimally applied during the learning process. Students are not used to learning by using technology and engineering from the material being taught. During the learning process students are not maximal in engineering and creating a technology product because during the learning process students tend to feel rushed due to time constraints and there are still students who are reluctant to ask questions and have an opinion, this also had a bad impact because in learning they did not do retries that cause practicum errors and the results of the experiments are sometimes not in accordance with the theory. However, due to confirmation discussions with other friends and students were given the opportunity to develop their knowledge, also the teacher acted as a facilitator and directed students if there were deviations or misconceptions, students' critical thinking skills could improve even though the time used was relatively short.

CONCLUSION

Based on the results of the research and discussion, it can be concluded that: There is a significant increase in critical thinking skills of class X students in learning using the STEM approach with the PBL learning model on Newton's Law of motion as indicated by the average N-gain value in the experimental class of 0.73, while the control class using conventional learning with a scientific approach has an average value of 0.56. Learning with the STEM approach and the PBL model is very effective for improving critical thinking skills as shown by the results of the effect size test resulting in a Cohen's d value of 1.49 in the high category. Students are given problems that exist in everyday life in learning so that they can foster students' critical thinking skills which are resolved by integrating STEM aspects. Learning with the STEM approach and the PBL learning model can improve students' critical thinking skills well because in the learning process it is focused on students who are required to think independently in solving problems in everyday life. The results may be different if applied in other schools. For further research, it is better to use more data or samples from this study so that the research results obtained will be more comprehensive. In addition, this study can be used as a reference for teachers in improving students' critical thinking skills using the STEM approach with a problem-based learning model.

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