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Optimizing of Physics Learning through PjBL-STEM Model to Improve Critical Thinking Skills and Students Responsibility Attitudes

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Abstract: Physics learning is a complex subject that required an extraordinary understanding. Based on the results of interviews at SMAN 4 DKI Jakarta, in Banda Aceh, critical thinking skill tests have not been carried out and student responsibility in following lessons. This research aims to optimize physics learning through the PjBL-STEM model, in order to improve students' critical thinking skills and lack of sense responsible attitudes. The research design that used in this research was a one group Pretest and Post-Test Design, it was involving 120 students in grade XI. The data collection techniques are carried out through observation, interviews, questionnaires and tests that are prepared based on indicators of critical thinking skills. This research data was analyzed using the average test, N-gain and paired sample t-test. The instruments used critical thinking skills tests and responsibility attitude questionnaires. The research results show that the average N-gain 0,67 is categorized as currently. The results of the responsible attitude questionnaire are in the effective category with an average of 367.2, From the findings of this research it can be concluded that the PjBL-STEM model can optimize physics learning in improving critical thinking skills and attitudes of responsibility.

Keywords: Critical Thingking Skills; PjBL-STEM; Responsibility.

Introduction

In the 21st century, education in Indonesia has been influenced by various revolutionary developments, including the 4.0 Industrial Revolution. To tackle the challenges posed by this revolution, schools must incorporate technology into the learning process, and educators must be more innovative in utilizing technological advancements to enhance education. In this century, students must have skills that called 4C, which are Creative Thinking, Critical Thinking, Communication and Collaboration. One of the skills that students must have is Critical Thinking. This complex thinking process consists of interpretation, analysis, inference, evaluation, explanation and self-regulation (Wartono et al., 2018; Novallyan et al., 2021). However, the physics evaluation results in critical thinking measurements that conducted by TIMSS were ranked 40 out of 42 due to the limitations of Indonesian students in their ability to think in this way. (TIMSS & PIRLS International Study, 2012). Critical thinking skills help students keep up with the demands that must be achieved to compete globally. that must be achieved to be able to compete globally (Aini et al., 2022).

Based on the results of observations that carried out at SMAN 4 DKI Jakarta, in Banda Aceh, it was found that there had never been a critical thinking skills test and there is no learning that had been carried out by students towards critical thinking skills at the school. The teaching and learning process system at this school has not trained students in critical thinking, this can be seen from the complexity of students' skills in completing

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tests or questions that require analysis, evaluation and creativity, they are still not trained enough in waves material. Therefore, the grades obtained by students have not reached the minimum completeness of criteria (KKM) (Pitriyani, 2021). The score that students must achieve is 78. Meanwhile, the results of the exam only reach an average of 68. High critical thinking skills will enable students to study a problem systematically, face obstacles in an organized manner, formulate innovative statements and design appropriate solutions to the problems faced (Carter et al., 2019). This is because the physics learning process that is taking place is not carried out in accordance with its essence.

This learning is only done by practicing and working on questions and a set of numbers using certain formulas. As a result of this learning, students are unable to think in order the student are less trained in solving problems with their thinking patterns. Apart from that, it was also found that students did not participate enough in the learning process, some of the routines shown that students were often late for class, did not finish their assignments, and did not follw the school's routine. As a result, the students lack of sense of responsibility. Creative thinking and responsibility are important skills that students need to develop in the context of problem-solving (Basri et al., 2019).

If we related to the new policy program by the Ministry of Education and Culture of the Republic of Indonesia (Kemendikbud RI) regarding to the freedom of learning, Nadiem Anwar Makarim as of December 11, 2019 stated that one of the main programs for freedom learning is active learning and education characteristics. In Indonesian Curriculum, using a real experience in learning with implementing the characters is already summarized clearly. According to Izza et al. (2020), teachers have the freedom to independently translate the curriculum before it is taught to class. Therefore, the teacher is able to answer all of the students' needs during learning and the learning objectives are also achieved successfully. One of the factors that causes students' low critical thinking abilities is conventional learning strategies and methods (Ihsan et al., 2019; Agnafia et al., 2019). To overcome this problem, there needs to be an alternative or a new innovation from educators and apply it in the learning process. Thus, the appropriate model to use for students in the 21st century is the STEM (integrated Project Based Learning model).

The PjBL model with a STEM (Science, Technology, Engineer, Mathematics) approach is a model with an integrated form of science or known as Natural Science, which is the study of natural phenomena that can be found in everyday life (Hasanah, 2020). This research is supported by previous research which stated that the average critical thinking ability of students with STEM-based PjBL learners is higher than those with conventional learning (Khoiriyyah et al., 2022; Priantari et al., 2020). The low of responsibility caused by the student's mindset and the awareness within the students themselves. One of the efforts to improve students' critical thinking and having a scientific attitude which is a responsibility toward a good learning is to use a STEM (Science, Technology, Engineering, and Mathematics) approach. Based on research results (Khoiriyah, Qomaria & Putera, 2022) said that using a STEM approach can improve students' critical thinking abilities. Likewise, according to (Sumarni, 2020) learning activities that can train critical thinking skills are the PjBL model which collaborated with the STEM approach. Learning with combining learning methods or models is done to maximize competencies to be achieved (Saputri et al., 2020).

Based on the description above, the researcher wants to conduct research with the title "Optimizing Physics Learning Through the Pjbl-Stem Model to Improve Students' Critical Thinking Skills and Responsibility".

Method

The type of research that use in this journal are quantitative and qualitative research. Quantitative research is using a varies numbers as a data collection and using statistics as a data analysis (Sugiyono, 2017). This research utilizing the experimental approach with a pre-experimental design. This study used a one group pretest-posttest design and the research subject is a whole class of student. During this research the test was carried out twice, first before using PjBL-STEM and the second test while using PjBL-STEM. This research has been carried out at SMAN4 DKI Jakarta, in Banda Aceh, located on Jl.T. Panglima Nyak Makam No. 19, Kota baru, Kec. Kuta Alam, Banda Aceh. This research was performed in the odd semester of the 2023/2024 academic year. The reason the researcher has chosen this location because of the problems faced regarding student learning outcomes that did not reach the minimum completeness criteria which were obtained from various kinds of problems and the lack of student responsibility in the learning process.

The population of this study was all of the students in grade XI IA SMAN4 DKI Jakarta, Banda Aceh, 279 students in total. The schools selected are relevant to the curriculum, which means they are relevant to the needs and interests of that population. The classes that were used as a sample were grade XI IA-1, XI IA-2, XI TI-1, and XI TI 2 with 120 students in total. The reason for choosing the students in this class as the subjects of this research was based on the consideration that the

students in this class were in the intermediate level, and their level of achievement was also in the intermediate level.

The procedures that used in this research have several stages. First, the research preparation stage, second the research implementation stage, and the final research stage. The data collection techniques used in this research were observation, interviews, questionnaires and critical thinking skills tests. The instruments in this research for collecting research data were in the form of validation sheets, the form of critical thinking skills test, and questionnaires. In this study, the normality test was carried out using the help of the SPSS 26.0 for window application. Hypothesis testing in this study used the Paired Sample T Test.

Result and Discussion

Results obtained from the research at SMAN 4 DKI Jakarta in Banda Aceh in optimizing Physics learning through the PjBL-STEM model were to improve students' critical thinking skills and responsibility. This research used an experimental class of 120 students in total. In the experimental class, the treatment was given using the PjBL-STEM model on *light wave* material with three meetings. At the first meeting, a pre-test was given to the students, then the teacher delivered learning material about light waves to the students. After delivering the material, the next activity was forming groups for each student and opening the LKPD. Then each group will discuss the LKPD that has been opened.

At the second meeting, each group will discuss the completion of the LKPD. In LKPD students have to do practicum, design projects and create projects. The project created is a simple *fly trap* that is assisted by light. Each class used different light and distance to see the effectiveness of the light on flies. At the third meeting, each group demonstrated each project work that has been done together. In this implementation, all groups will be discussed projects created by another group. At this stage, students will also answer post-test questions and fill out a questionnaire regarding this learning activity.

The results of this research were obtained from data collection through two data collection processes (pretest and posttest). At the pretest stage, students are asked to answer several questions regarding the material of *light waves*. This aimed to determine the student's initial abilities before the treatment being given. After getting an initial score at the pretest, students are given treatment using the PjBL-STEM model and at the end of the learning they are given a posttest.

Students' critical thinking skills can be seen based on critical thinking of the indicators. Before analyzing it as a whole part. First, we need to analyze each indicator of critical thinking, namely: (I) Elementry Clarification, (II) Basic Support, (III) Inference, (IV) Advence Clarification, and (V) strategy and tactics. The results obtained can be seen in the following table:

Table 1. Average Score of Critical Thinking Indicators

Pretest					Posttest				
Critical thinking indicators									
I	II	III	IV	V	I	II	III	IV	V
31.06 %	6 %	28.3 %	35.6 %	17 %	95 %	95.4 %	29.6%	93.9%	40 %

Source: SMAN 4 DKI Jakarta, Banda Aceh, 2023 (processed data)

Based on the N-Gain data below, it shows that there are differences in the increase in critical thinking of students taught using the PjBL-STEM model. In this case, it is in accordance with the results of Suardi's research (2020) which explains that the improvement of students' critical thinking skills can be seen from the average N-gain value obtained by students in the class that was the research sample. The experimental class or class that uses learning with PjBL-STEM has a high average N-gain value.

Tabel 2. Data *N-Gain* Score

Pretest	23.6	N Gain
Posttest	70.96	0.67

Based on Table 2, the average Ngain of 0.67 is categorized as moderate. This shows an increase between before and after being given treatment, namely using the PjBL-STEM model. The data in this study were tested for normality using the Kolmogorov-smirnov. Test using IBM SPSS Statistics Subscription. To find out whether the data is normal or not, if sig > 0.05 then it is normal and if sig < 0.05 it can be said to be abnormal. The calculation results obtained are as follows.

Table 3. Data Normality Results

Statistic		df	Sig
Pre	.081	120	.051
Post	.079	120	.065

Based on the output, it is known that the two variables had tested statistics of 0.081 and 0.079 with significance values of 0.051 and 0.065. In this test, a decision is made to reject H0 if the significance value is smaller than the significance level (0.05). It is known that the significance value is greater than the significance level, so a decision is fails to reject H0 so it can be

concluded that the two variables are normally distributed.

After the normality test is carried out, a hypothesis test can be done by using the t-test which used to determine, if there are significant differences between classes that were previously taught without treatment and classes that used the PjBL-STEM in improving students' critical thinking skills. The hypothesis test used in this research is a parametric statistical test, that is the paired sample T-test. This test is used to make a decision, whether the hypothesis is accepted or rejected. The hypothesis in this research is as follows.

Table 4. Paired Sample T-Test Results

		Mean	N	Std. Deviation	Std. Error Mean
Pair	pre	37.9583	120	14.47246	1.32115
	post	66.5833	120	15.36644	1.40276

Based on the output, it is known that the average pretest score is 37.9583 with a standard deviation value of 14.47246, while the average posttest score is 66.5833 with a standard deviation value of 15.36644. The average difference is -28.625 with a standard deviation value of 14.14158. It is known that the t-test statistic has a value of -22.174 with a significance value of 0.000. In this test, a decision is made to reject H0 if the significance value is smaller than the significance level (0.05). It is known that the significance value is smaller than the significance level, so it can be concluded that there is a difference between before and after values. So, it can be concluded as follows.

H0 = There is no difference in the use of PjBL-STEM in physics learning to improve students' critical thinking skills. Determine the level of significance. Ha = There are differences in skills before and after being taught using PjBL-STEM in improving students' critical thinking skills.

Student Responsibility Data

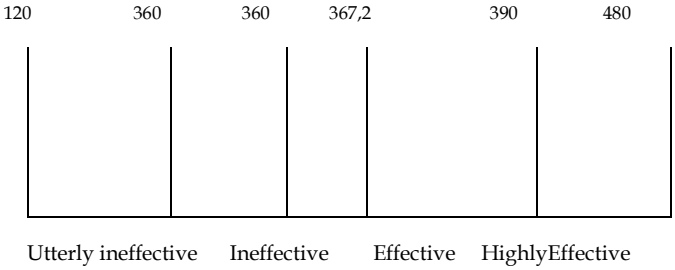
Based on this data, the steps that can be taken to find out the attitude of each respondent towards learning physics is using PjBL-STEM. 1). Maximum score, that is the maximum score obtained by each respondent multiplied by the number of respondents. it is written as 4 x 120 = 480. 2). Minimum score, that is the minimum score obtained by each respondent multiplied by the number of respondents and it is written as 1 x 120 = 120. 3). Median value, that is the sum of the maximum total score and the minimum total score divided by two. (480 + 120):2=300. 4). Quartile value 1, that is the sum of the total minimum scores and the median divided by two. (120+300)/2= 210. 5). Quartile value 3, that is the result of adding the maximum score with the median divided by two. (480+300)/2= 390

Table 5. Scores Limits for Each Category

Highly Effective	Quartile 3 ≤ × ≤ Maximum Score	390 – 480
Effective	Median ≤ × < Quartile 3	300– 390
ineffective	Quartiles 1 ≤ × < Median	360 – 300
Unterly ineffective	Minimun Score ≤ × < Quartile 1	120 – 360

Based on the distribution of the results of each respondent's scores, such as the distribution table of respondents' data collection results. The total scores obtained for all respondents are as follows.

Table 6. Results of Responsibility Questionnaire Scores



Based on the data table 6, the student's responsibility received a final score of 367.2, which states that it is effective. This is shown by the respondent's total score which lies between the score which is the score limit in the effective category. Therefore, learning using the PjBL-STEM model is effective in increasing students' responsibility.

Students' Critical Thinking Skills Based on Critical Thinking Indicators

According to Pasquinelli et al. (2021) in their research stated that in training critical thinking skills requires habituation to critical analysis of information and problem solving. Students' critical thinking skills are measured from critical thinking indicators in solving problems. Indicators of critical thinking are: ((I) Elemntry Clarification, (II) Basic Support, (III)Inference, (IV) Advence Clarification, and (V) strategy and tactics. The following graph shows how to Improve critical thinking skills using an PjBL-STEM approach in physics learning.

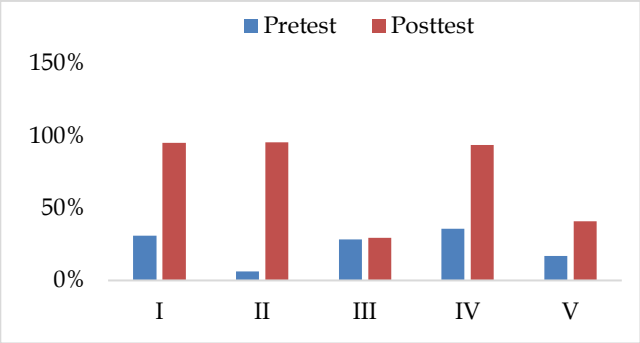


Figure 1. Average critical thinking answers indicator

Elementary Clarification

Providing a simple explanation is the goal of the sub-indicator answering questions about an explanation or challenge. Based on Figure 4.1 above, it can be seen that the average value of students before being treated obtained a percentage of 31.06% in the indicator of giving a simple explanation. In this essay question, students are presented with a statement about light waves; students are also expected to be able to formulate the problem with a simple explanation. This indicator measures students' skills in answering analytical questions from a statement about light waves. This indicator obtained a good category because students already understood, after being given treatment taught using the PjBL-STEM model obtained an average percentage value of 95% categorized as very good. This can happen because the PjBL-STEM model requires students to ask questions and define problems that can support learners to understanding the problem. In line with Khoriyah, et al. (2020), PjBL-STEM focuses on solving problems experienced in everyday life.

Basic Support

The second indicator is basic support. In this indicator is measured through question number 2, students are presented with a statement containing a perfectly reflected ray, from the statement students are expected to identify a statement that is true or not based on relevant sources. Before being given the treatment students obtained an average percentage value of 6% by having a smaller category, however after being given the treatment of learning taught using the PjBL-STEM model students obtained an average percentage value of 95.40%, which was categorized as very good. This is because during the learning process the teacher provides opportunities for students to identify a question based on a strong source of the correct observation and source-finding process.

In education, the PjBL-STEM model provides learning that forms collaborations that will help students gather information, analyse, and solve problems that can hone their abilities to build their basic skills. This is in line with the opinion of Handayani (2013) who said that STEM is an approach that contains several disciplines collaborating in learning that helps students collect, analyze and solve problems to make students able to build their skills.

Inference

The purpose of the third sub-indicator, namely making conclusions and considering the results, is that students can decide conclusions from observations and analyse them. The achievement of this sub-indicator is measured through essay question number 3, students are expected to be able to decide the conclusion by being given a question about the concept of the working principle of Pascal's law and then considering possible answers, because in this question many of the students were fooled by the final results obtained not following with the working principle of Pascal's law. This indicator measures students' ability to make the right conclusion. Before being given the treatment students obtained an average percentage value of 28.3% by having a deficient category, but after being given the treatment of learning using the PjBL-STEM model, students obtained an average percentage value of 29.6% in the deficient category. This is because during learning the teacher requires students to conclude the observations of the problems given. Still, students are less able to make an appropriate conclusion about the observations made, so in this indicator, students cannot to reach a good category.

The STEM education process consists of collaborative, creative learning and gathering information that allows students able to find solutions to problems faced in real life so that students can conclude possible solutions to solve these problems. This is the opinion that Robert & Cantu (2012) expressed that STEM learning can help students solve problems and draw conclusions by applying it to it to science, technology and mathematics. In this case, it can train students' skills to make the right decisions, and be the solution.

Advanced Clarification

The fourth indicator is to provide further explanation, such as identifying assumptions. This indicator is measured through essay question number 4. Students are presented with a statement about light waves and students are expected to provide assumptions related to 2 things about light waves.

This indicator measures students' skills to provide assumptions on problems that are analyzed appropriately. Before being given the treatment, students obtained an average percentage score of 35.6%. But after being given the treatment of learning using the PjBL-STEM model obtained an average score of 93.90%

categorized as very good This is because the teachers encourage students to take action, choose possible answers to a problem and familiarise them with giving their opinions among peers, enabling them to solve problems collaboratively.

In STEM education, there are learning process activities that contain collaboration and creativity when students are faced with problems. With this problem, students gain complete knowledge and are more skilled in conveying further explanations based on concepts that are sought out or already exist. This is in accordance to the statement by Beers (2011) that STEM learning has collaborative, creative activities and communicates real problems so that students can find the right solution to be given a further explanation. This process requires students to take part in improving their skills in the aspect of active thinking.

Strategy and Tactic

The fifth indicator is strategizing and tactics, such as deciding on an action. This indicator is measured through essay question number 5, students are presented with a statement about light passing through a medium and are expected to formulate the problem in choosing the correct statement. This indicator of developing strategies and tactics measures students' skills in making the right decisions by considering the analysis result. Before being given the treatment, students obtained an average percentage score of 17%, after that, they obtained an average score of 40.90% categorised as less.

The reason for low scores in this indicator could be that the teacher expects students to take action to select a possible solution to a problem. However, in this case, students may need help choosing the correct action to solve the problem. As a result, they may not be used to select accurate solutions. This could be why the average percentage value obtained by students in this indicator is low.

Improvement of Students Critical Thinking Skills

The learning process used the PjBL-STEM model to improve students' critical thinking skills. Before carrying out learning, researchers conducted an initial test (pretest) on students. The mean pretest value obtained was 23.6. This is what makes researchers decide to continue research. After being given treatment, the researchers conducted a final test (post-test). The posttest value obtained was 70.96.

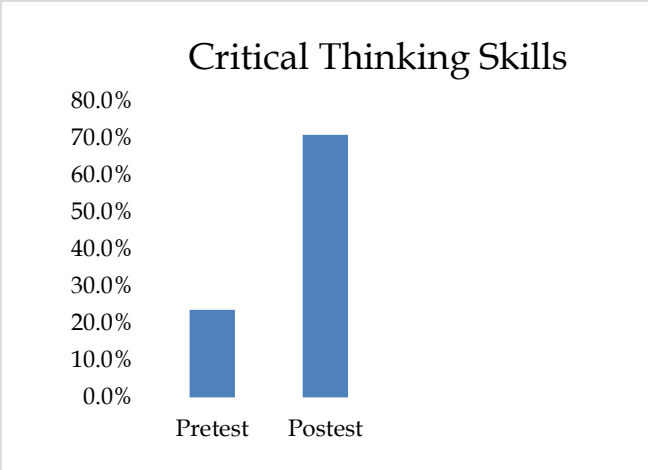


Figure 2. Overall pretest and posttest scores of critical thinking skills

According to the data on the figure 2, the average value of students has increased. Specifically, the increase in the average student score on the post-test is greater than the average score on the pretest. Therefore, we can interpret the results to mean that the posttest score is higher than the pretest score.

The increase in critical thinking skills obtained by students is 47.36. Based on the N-Gain data below, there are differences in the increase in critical thinking of students taught using the PjBL-STEM model. In this case, the results of Suardi's research (2020) explain that the improvement of students' critical thinking skills can be seen from the average N-gain value obtained by students in the class that became the research sample. The experimental class or class that uses learning with PjBL-STEM has a high average N-gain value.

Student Responsibility Attitude

Based on the results of research and data analysis, it can be seen that students' responsible attitude towards the learning process by applying the PjBL-STEM model is categorised as effective.

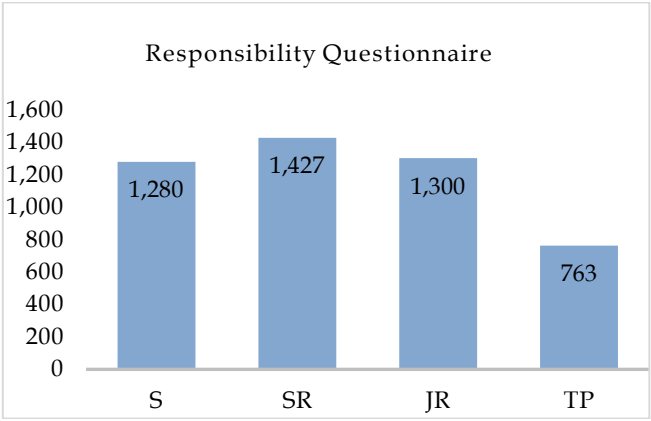


Figure 3. Responsibility questionnaire graph

Figure 3 shows that the percentage of student answers in the SR (often) category averaged 1,427 with a high category. Students feel they can participate, be active, respect others, cooperate, motivate others, help others, be leaders, express opinions and ask for help. However, based on the results of observations, there are still some students who are categorized as lacking in activeness, expressing opinions and expressing opinions. In addition, most students' responsibility in leading and asking for help is generally still in the less/sufficient criteria.

Based on the understanding that an attitude of responsibility involves the ability to recognise taking responsibility for actions and decisions, it can be assumed that students a good attitude of responsibility tend to have better critical thinking skills**.**

Relationship between Critical Thinking Skills and Responsibility Attitude

Critical thinking and responsibility have a close relationship. Critical thinking is analysing and evaluating a situation or problem objectively, rationally, and logically. Meanwhile, an attitude of responsibility is a person's mental and moral attitude to take responsibility for the actions and decisions taken. In this context, critical thinking is very important in developing a good attitude of responsibility. With critical thinking, students can see and understand the consequences of every action or decision taken. They can analyze situations in depth, consider various points of view, and predict the impact of the actions to be taken. In addition, an attitude of responsibility is also driven by the ability to think critically in identifying and solving problems. By thinking critically, one can identify the root of the problem in a more systematic and logical way. They can then take responsible action to solve the problem, be it independently or by involving other related parties. This is in line with the opinion of (Diah, 2023) that the combination of critical thinking and responsible attitude can improve students' learning ability.

Therefore, critical thinking and responsibility have a complementary relationship. Critical thinking helps one in making responsible decisions, while an attitude of responsibility requires the ability to think critically in analyzing, evaluating, and making wise decisions. The combination of these two things will help a person develop a good attitude of responsibility in everyday life.

Relationship between Critical Thinking and Responsibility Attitude with PjBL - STEM Model

PjBL model integrated with the STEM (Science, Technology, Engineering, and Mathematics) approach can improve learners' critical thinking skills and scientific responsibility attitude. This integration allows learners to understand and develop skills in the fields of science, engineering, and mathematics while playing projects that require critical thinking and responsibility. This is in line with the opinion (Novi, 2020) that the PjBL-STEM model plays a project that requires real solutions to problems that exist in the real world. This triggers learners to think critically and evaluate the steps taken to achieve the project goals. According to Ennis (2013), The Lucas the lucas educational Foundation (2005), Back (2017), the third relationship is as shown in the table 7.

Table 7. Relationship between Crtical Thinking, PjBL-STEM and Responsibility Attitude

Critical Thinking	PjBL	STEM	Responsibility
Elementary Clarification	Essential Question	Identify & Define Problem	Participation, Activiness
Basic Support	Design a Plan for the Project	Create Prototype	Cooperation, Motivator
Inference	Create Schedule	Refine	Leadership
Advanced Clarification	Asses the Outcome	Communicate)	Expressing Opinion
Strategy and tactic	Evaluate the Experiece	Evaluate or Test	Requesting Help

This model encourages learners to work together in teams to achieve project goals, the cooperation and collaboration required in this process allows learners to think critically and take responsibility for mistakes or difficulties encountered. The active observation of learners in the learning process helps them develop critical thinking skills and an attitude of responsibility, as they have to monitor, analyze and adapt the strategies taken to achieve project goals. The relationship between critical thinking and responsibility attitude in the PjBL-STEM model is a positive and consistent relationship, which is recognized especially in the improvement of learners' critical thinking ability and scientific responsibility attitude.

Conclusion

Based on the results of the study, it is concluded that there is an increase in critical thinking skills and attitudes of responsibility in physics learning taught with the PjBL-STEM model.

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Author Contributions

The lead author, Khairun Nisah, contributed to designing and conducting the research and writing the article. The second and third author, Saminan and Muhammad Syukri, Markisni contributed in guiding the writing of the article to completion. The fourth, fifth, sixth and author, Yusrizal, Elisa, Fitriani contributed to validate the instruments of the article. All authors have approved the version of the manuscript to be published preparation.

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Conflicts of Interest

There is no conflict of interest in this research.

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