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# The Effectiveness of the PjBL-STEM Model on Students' Critical Thinking Ability in Science Learning

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***Abstract:*** *This study aims to prove the effectiveness of Project-Based Learning integrated STEM on students' critical thinking ability in science learning. This research is a quasi-experimental study with a pretest-posttest control group design. The research population was grade VIII students of SMP Negeri 1 Dukun for the 2022/2023 academic year, comprising six classes. Meanwhile, the research sample was selected using a cluster random sampling technique; VIII E was the experimental class, and VIII F was the control class. The experimental class received the PjBL-STEM model treatment, while the control class was the PjBL model, the model that has been used before. This research data is the difference in pretest-posttest scores of students' critical thinking ability, which was analyzed by the right-sided t-test and N-Gain test. The study results showed tcount>ttable, and the experimental class had an N-Gain value of 0.417, while the control class was 0.246. So, it can be proven that the effect of the PjBL-STEM model on students' critical thinking ability in science learning is more significant than the PjBL model. Then, this study implemented that the Project-Based Learning model integrated with STEM can be an option and learning innovation to further increase students' critical thinking ability.*

***Keywords:*** *PjBL-STEM Model, Critical Thinking Ability, Science Learning*

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## INTRODUCTION

Currently, Indonesia is in the era of industrial revolution 4.0 and has entered the era of society 5.0 (Nastiti & 'Abdu, 2020; Teknowijoyo, 2022). In the course of the revolutionary era in the 21st century, it is unavoidable that the challenges and problems that arise in everyday life are of high complexity (Fitriyah & Ramadani, 2021). In addition, in the era of the industrial revolution 4.0 in the 21st century, job competition is increasingly competitive, and the demands for a worker's skills are even higher (Teknowijoyo, 2022). According to the Ministry of National Development Planning of the Republic of Indonesia (2019), a person's performance depends on the quality of his education. In other words, education is one aspect that can support performance or human resources to compete in the era of the industrial revolution 4.0 in the 21st century (Ariyatun & Octavianelis, 2020). Therefore, Education in Indonesia is demanded to prepare a generation that can master skills by the demands of the 21st century. Quality education can be improved by reforming learning (Ariyatun & Octavianelis, 2020). One is the shift from the learning process, which is usually still limited to low-level thinking, towards learning more directed at higher-order thinking skills.

Critical thinking includes higher-order thinking skills and is one of the 4C competencies in 21st-century skills (Chusni, Saputro, Suranto, & Rahardjo, 2020). Critical thinking is a person's ability to solve problems by analyzing a subject in a particular direction (Chusni et al., 2020; Rahardhian, 2022). Everyone has the potential to be able to think critically, but not everyone can develop their critical thinking skills (Lieung, Rahayu, & Yampap, 2021). So that sometimes, in a condition, a person is less



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able to solve problems in daily life. For example, in the case of student entrepreneurship projects during the Covid-19 pandemic, the project did not run smoothly due to social restrictions and different market conditions, and students suffered losses. But some of them can succeed and profit more from their sales. The ability of students to deal with problems in completing the assignment of entrepreneurship subjects is related to the ability to think critically of someone different. The ability to think critically means design, management, innovation, and processing and calculating capital and product selling prices according to the conditions. Some of these abilities influence one's entrepreneurial success (Burhanuddin, Pambudy, & Priatna, 2107).

Students' critical thinking ability can be influenced by several factors, such as gender, Intelligence Quotient (IQ), motivation, instruments, independent learning, teacher and student interaction in learning, approaches, methods, and learning models (Chusni et al., 2020; Hasanah, Sunarno, & Prayitno, 2020; Lestari, Putri, & Wardani, 2019; Olenggius, Wibowo, & Susanti, 2020). In addition, according to Mansur & Juhji (2020), critical thinking ability correlates with mastery of concepts and problem-solving. Based on the analysis of the results of ONMIPA questions in Wahidin & Romli`s research (2020), it is known that students must master essential concepts to underlie critical thinking processes or assumptions of a relevant concept when dealing with natural phenomena in students' lives. For example, in a condition students must use scientific values or attitudes to determine attitudes when faced with natural phenomena or real-life problems.

Natural Sciences (IPA) is one of the subjects taught in junior high school. Natural Science (IPA) is a relevant topic for improving students' critical thinking ability because the concept of Natural Science is closely related to life and the surrounding natural environment (Wahidin & Romli, 2020). Meanwhile, science learning is a complex activity in which students can develop knowledge and skills and then relate them to science concepts acquired during the learning process to solve problems in everyday life (Wulandari, Wijayanti, & Budhi, 2018). Therefore, the learning system in the 2013 curriculum, along with several science learning competencies, has been designed to support the development of critical thinking skills as one of the higher-order thinking skills (Mukmin, Radiyah, & Yusuf, 2021).

However, based on research by Hasanah et al. (2020), it is known that the percentage of critical thinking ability for junior high school students is still in the low category of 46.87%. Schools in Indonesia implemented the 2013 Curriculum, which has many innovative models. However, many teachers still carry out the learning process using conventional learning models, making learning less likely to be student-centered (student-centered learning) (Chusni et al., 2020). The same thing happened at SMP N 1 Dukun. In several meetings, this school has implemented the PjBL model, but it is known that students' critical thinking skills at this school are still relatively low. One can be seen from the analysis of student answers on the explanatory aspect indicator, where the completeness score of one of the questions is only 78%. In addition, it is known that the average UAS IPA results for SMP Negeri 1 Dukun students in the previous school year were still around 30-50. According to Komariyah & Laili (2018) and Mutmainnah, Suhartono, & Suryandari (2021), students' critical thinking skills are correlated with learning outcomes. So, critical thinking ability is essential to learning in school.

One of the efforts to stimulate students' critical thinking skills is developing and selecting learning models and approaches. The STEM approach is one approach that is relevant to the 2013 curriculum and can accommodate and develop students' critical thinking skills (Pahrudin et al., 2021; Widya, Rifandi, & Laila, 2019). According to Pahrudin et al. (2021), students can develop their critical thinking skills through the stages or process of STEM learning. Apart from integrating the four components, there are science, technology, engineering, and mathematics, in a lesson, the STEM approach also allows students to have direct experience in solving problems in the surrounding environment through the design or redesign of technology in a project (Davindi, Sennen, & Supardi, 2016).

Of course, the STEM approach must be combined with a suitable learning model. The Project Based Learning (PjBL) model includes an innovative learning model according to the 2013 curriculum, where the learning process is through project activities (Malahayati, 2015). The PjBL model and the STEM approach have similar characteristics and goals, directing students to solve problems with a product or technological result. Hence, the model is the right one to integrate with the STEM approach (Dywan & Airlanda, 2020). The PjBL learning model integrated with the STEM approach is called the PjBL-STEM model. According to Rush (2015), the PjBL-STEM learning stages are already integrated into five stages (syntax): reflection, research, discovery, application, and communication. Unlike the learning steps of the PjBL model, the PjBL-STEM step directs students to work on projects studied in


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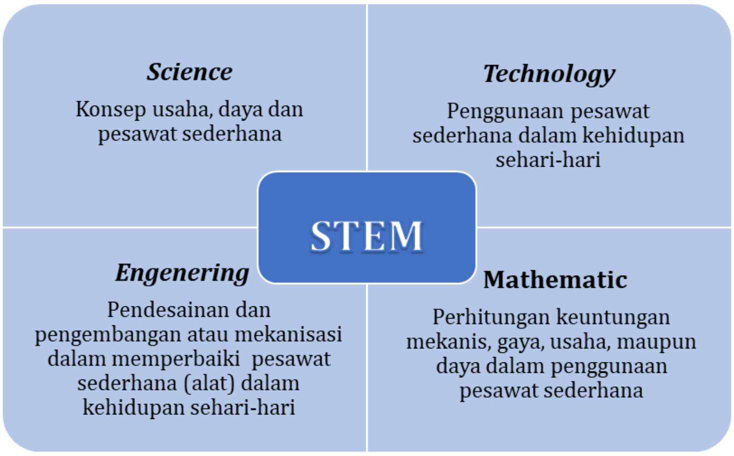
detail based on the four STEM components: science, technology, engineering, and mathematics. When in the process, this model can improve students' critical thinking, mainly when applied to science learning. For example, when faced with a problem at the beginning, students must think critically, from interpreting to analyzing the appropriate technology to solve the problem (Sri, Gandi, Haryani, & Setiawan, 2021)

Research on applying the PjBL-STEM model has been carried out previously with elementary, junior high, and high school students as research subjects (Rahardhian, 2022; Sri et al., 2021). However, similar research was found with limitations on natural science learning problems with business materials and simple planes, namely research conducted by Pratiwi, Zulirfan, & Yennita (2022). In the previous studies, STEM-based projects were carried out online with provided STEM kits. It is one of the limitations because students should be freed to do STEM projects without being equipped with a STEM kit. Through these limitations, to determine the model's effectiveness, this research was carried out by replacing the STEM kit with student worksheets adapted to the stages of the PjBL-STEM model to help the success of STEM projects. Integrating STEM on the subject matter of work and simple machines can be seen in Figure 1.




**Picture 1.** STEM Integration on The Subject Matter Of Work and Simple Machine

According to Amelia, Tegariyani, & Santoso (2021), the PjBL model and the STEM approach are suitable for science learning and can develop 21st-century skills, including critical thinking ability. Furthermore, based on some of the results from previous studies, they know that the PjBL-STEM model affected students' critical thinking ability (Dywan & Airlanda, 2020; Indriyana & Susilowati, 2020; Pratiwi et al., 2022). However, the analysis used by some of these studies is a two-way test analysis. Seeing that there are positive results in the results of the two-way analysis, this study focuses more on proving the effectiveness of the PjBL-STEM model on students' critical thinking skills by using a one-way test analysis. Therefore, by integrating the STEM approach into the PjBL model, it is hoped that it will have a more significant effect on the critical thinking ability of junior high school students in science learning than the control class.

The indicators of critical thinking used in this study are indicators according to Facione; there are interpretation, analysis, inference, evaluation, explanation, and self-regulation. The results of this study inform about the application of the project learning model in junior high school science learning with a different perspective, with redesign activities in it. In addition, this research provides a choice of models that can improve students' critical thinking skills as one of the 4C competencies that students must have in learning. 21st century.

## METODE

### Place and Time of Research

This research was conducted at SMP N 1 Dukun for the 2022/2023 academic year, more precisely, in July-September 2022.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**Types of Research and Sampling**

This research was a quantitative research that used a quasi-experimental method to prove the effectiveness of a treatment on a predetermined dependent variable. The dependent variable of this study was the critical thinking ability in science learning. Then, the independent variable was an application of the project-based learning model integrated with the STEM approach (PjBL-STEM). The research design used the pretest-posttest control group design, which can be described in Table 1.

**Table 1.** Pretest-Posttest Control Group Design

| Class | ***Pretest*** | Treatment | ***Post-test*** |
|---|---|---|---|
| Experiment | $O_1$ | $X_1$ | $O_2$ |
| Control | $O_3$ | $X_2$ | $O_4$ |

(Sugiyono, 2019)

The participants in this study were eighth-grade junior high school students in the first semester. The research sample group was selected through random cluster sampling based on data on the final semester exam scores of students in the previous academic year, which consisted of six class groups. Before random selection, a homogeneity test was carried out on the six data groups to determine that all data groups were homogeneous. The sampling results obtained two classes: class VIII E as the experimental class and class VIII F as the control class. The experimental class consisted of 32 students, while the control class had 31 students.

**Data Instruments**

The instruments in this study consisted of test and non-test instruments that previous experts had validated. The non-test instrument was in the form of observation sheets for implementing teacher and student activities, which function to obtain supporting data for implementing syntax in the two research classes. This instrument was made regarding the PjBL-STEM model syntax for the experimental class and the PjBL model syntax for the control class. At the same time, the research test instrument was in the form of critical thinking ability questions, which were arranged based on indicators according to Facione and function to obtain pretest and post-test value data. The instrument for this research was tried out before the research was conducted. The pretest and post-test questions used each consisted of six essay questions. The pretest and post-test scores obtained were then used to obtain the difference in scores (gain scores) of students' pretest-posttest critical thinking abilities, which are the main data in this study.

**Data Analysis**

The results were analyzed using several tests, namely the normality test and homogeneity test (requirement test) and the N-gain test and hypothesis testing.

$$N\text{-}gain = \frac{\text{Score after treatment} - \text{Score before treatment}}{\text{Highest score} - \text{Score before treatment}}$$

The N-gain calculation results obtained are then categorized based on Table 2.

**Table 2.** Gain Rate Category

| No | Level | Category |
|---|---|---|
| 1 | High | 0.7 – 1.0 |
| 2 | Medium | 0.3 – 0.7 |
| 3 | Low | 0.0 – 0.3 |

(Hakes, 1998)

Hypothesis testing determines whether the independent variable's effect is significant on the dependent variable. Testing the hypothesis of this study used the right-sided t-test, which was carried out through an independent sample t-test with the help of the IBM SPSS Statistics 23 application. The independent sample t-test of this study was carried out on the difference between students' pretest and


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post-test (gain score), which was intended to prove the significant effect of the PjBL-STEM model on students' critical thinking ability in junior high school science learning. At the same time, the one-tailed test was chosen because it can prove the tendency of the direction of the model's influence. In this study, the direction of the hypothesis is to the right or positive (greater).

The first research procedure was the preparatory stage of a survey or school observation and preparations for making and validating the instruments used. Furthermore, the implementation phase began with the experimental and control classes' pretest activities. Then implement the model or learning activities in class according to the syntax of the model in each research class. At the end of the lesson, post-test activities were carried out with the instrument of students' critical thinking ability. Then the final procedure was the completion stage in the form of data analysis and concluding (test decisions) based on the data analysis process results.

### Research Procedure

The research starts with school observation to find existing problems. Next is the preparation of proposals and permits. After that, the instrument was made, and the instrument validation test was carried out. Then sampling was carried out and continued with applying the model (learning) in each experimental class. Before learning, a pretest was conducted to measure students' initial critical thinking abilities.

Appliying the model (learning) was carried out in face-to-face meetings (offline learning) and began to be implemented so that most of the learning process could be carried out in direct collaboration in class. However, some project work processes are carried out or done by students outside class hours with monitoring from the teacher. The study was conducted in 3 meetings (five hours of lessons) in the experimental class and 2 (four hours of lessons) meetings in the control class. The difference in the number of study hours in the two classes is because it takes more time to explore activities in the PjBL-STEM model syntax than in classes with the PjBL model.

The PjBL-STEM model syntax as a form of treatment in the experimental class consists of five stages, namely reflection, research, discovery, application, and communication. Then, the PjBL model syntax was a control consisting of six stages, namely starting with an essential question, designing a project plan, creating a schedule, monitoring the students and the progress of the project, assessing the project results, and evaluating the project. The teaching and learning process in both research classes began with problem presentation activities from the teacher. It continued with discussion activities and project work by each group following the RPP or the syntax of the learning model in each research class with the help of student worksheets. When learning was complete, a posttest was carried out to measure students' critical thinking ability after being treated with both models. The research data were then analyzed using a predetermined test. Then the last conclusion is drawn based on the results of the data analysis.

## RESULTS AND DISCUSSION

### Data Description

This research data is in the form of pretest-posttest difference data (gain scores) on students' critical thinking skills in the experimental and control classes in science subjects, business material, and simple machines. The difference in this value is obtained from the calculation of the post-test score minus the pretest value of students' critical thinking skills and can also play a role in seeing an increase or change in student scores. A statistical description of the data of this study can be seen in Table 1.

**Table 3**. Statistical Description of Research Data

| Description | Experimental Class (PjBL-STEM) | Control Class (PjBL) |
|---|---|---|
| Average | 24.80 | 15,12 |
| Standard Deviation | 10.01 | 9,11 |
| Variant | 100.22 | 83.01 |
| Minimum Value | 5.75 | 0.69 |
| Maximum Value | 45,63 | 37.00 |
| Range | 39.88 | 36,31 |


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Table 1 shows that based on the descriptive analysis, there are differences in the results of the pretest-posttest scores of critical thinking skills in the experimental class and the control class, where the results in the experimental class seem to be higher than the control class. Meanwhile, a comparison of the frequency distribution of the increase or difference in the value of students' critical thinking skills in the control and experimental class can be seen in Figure 2.

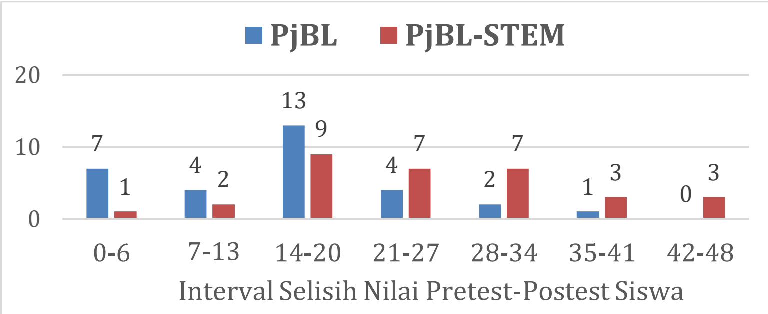


**Figure 2**. Comparison of the frequency distribution of the difference in pretest-posttest scores for students' critical thinking skills in the experimental class and the control class

Figure 2 shows that the frequency distribution of the difference in pretest-posttest scores (gain scores) for students critical thinking skills in the two study classes is at the same interval at most, namely in the range of 14-20. Although the frequency of differences in the value of the control class in the range of 14-20 is higher than the experimental class. However, the distribution of scores in the control class was mostly in the range below, and none were in the highest interval group. In contrast to the distribution of the difference in value in the experimental class, the difference in value is in all ranges and some values are in the highest range. It explains the increase in value due to better treatment in the experimental class than in the control class. Furthermore, the increase in students' critical thinking ability can also be seen through a comparison of the average difference in value for each indicator, as shown in Figure 3.

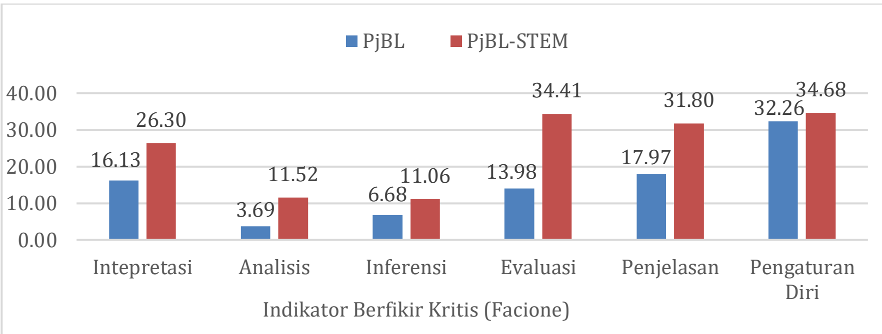


**Figure 3**. Comparison of the Average Of Gain Score of Each Indicator of Students' Critical Thinking Ability

Figure 3 shows that the average difference of the pretest-postest score (gain score) of each indicator of critical thinking ability in the experimental class is higher than in the control class. These results are the same as the research of Indriyana & Susilowati (2020), which showed that the average score for each indicator of students' critical thinking ability in the experimental class is higher than in the control class. Then, this table shows that the highest mean difference between the two study classes lies in the self-regulation indicator, with a value of 34.68 in the experimental class (PjBL-STEM model) and 32.26 in the control class (PjBL model).

The self-regulation indicator is located at number six in the pretest and post-test questions of students' critical thinking ability. The question concerns the application of the pulley type based on its mechanical advantage, which is closely related to the topic of the problem solved through project learning in both research classes. As seen from the students' post-test answers, as shown in Figure 4,


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after receiving the PjBL-STEM model treatment, it was found that in the experimental class, most students could answer the questions according to the answer key (correct) by drawing a compound pulley.

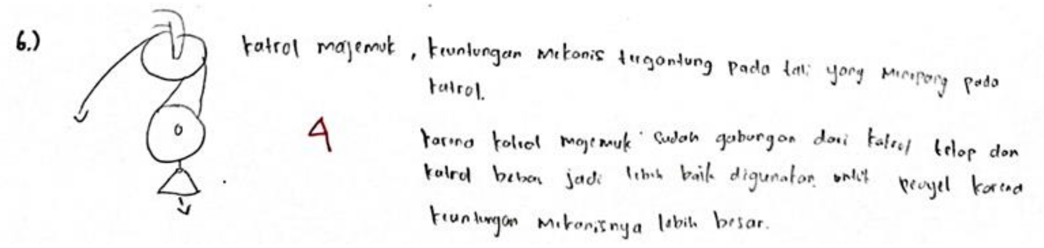

**Figure 4.** Sample Answers for Number Six Students In Experiment Class

**Figure 5.** Sample Answer Number Six In Control Class Students

The results of the post-test answers and the difference in the average score, which is higher in the experimental class, prove that the PjBL-STEM model learning can facilitate students in improving their thinking ability on self-regulation indicators. In the PjBL-STEM learning model, indicators of self-regulation can be trained through student activities at the application and communication stages. The application stage consists of student activities in realizing project designs into product forms in the form of crane prototypes and conducting experiments. Students' ability to manage time and be responsible so that the product can be completed at the specified time can train students to increase their critical thinking ability as an indicator of self-regulation (Hasibuan, Sari, Syahputra, & Nahadi, 2022). At the same time, self-regulation was trained in presentation and question-and-answer activities at the communication stage.

Based on Figure 3, it is also known that the lowest average difference in indicator values in the experimental class lies in the inference indicator, with a value of 11.02. Then seen from the results of working on these questions, the average student in the experimental class still needed to answer the questions correctly. It was seen from several students only determined conclusions without including how to do it or only based on the logic seen in the questions, as shown in Figure 6 and Figure 7.

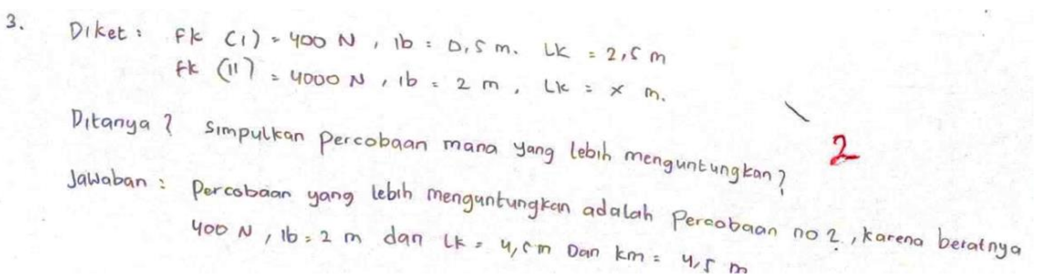

**Figure 6.** Example I Answer Number Three Experiment Class Students


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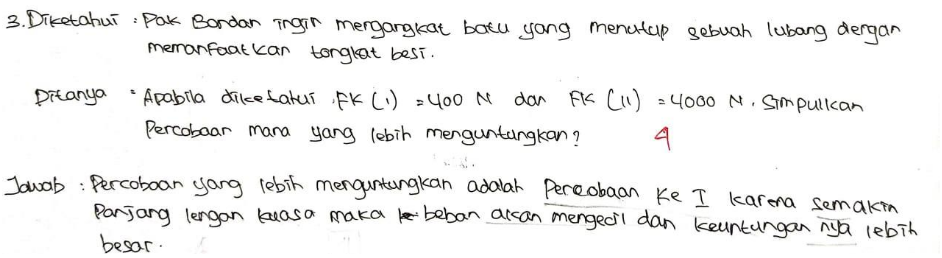
3. Diketahui : Pak Bardan ingin mengangkat batu yang menutup sebuah lubang dengan memanfaatkan tongkat besi.
Ditanya : Apabila diketahui FK (I) = 400 N dan FK (II) = 4000 N. Simpulkan Percobaan mana yang lebih menguntungkan?
4
Jawab : Percobaan yang lebih menguntungkan adalah Percobaan ke I karena semakin Panjang lengan kuasa maka beban akan mengecil dan keuntungan nya lebih besar.

**Figure 7.** Example II Answer Number Three Experiment Class Students

Even though several activities have been facilitated at the PjBL-STEM syntax stage to improve analysis indicators, it is known that some students still need to get used to it and need direction or teacher assistance in making conclusions. Then the time for the experiment, which was only one hour of lessons when applying the PjBL-STEM model, could also be a factor in students' low inference abilities (Hasanah et al., 2020). On the other hand, the lowest average score difference in the control class lies in the analysis indicator, with an average value of 3.69. That is because, in the PjBL learning model, there are no experimental activities which are data collection and analysis activities; according to (Sumarni & Kadarwati, 2020), these activities can facilitate analytical skills. In addition, the design of the pulley product carried out in project work in the PjBL model learning in the control class has been directed, or an example has been presented so that students' analytical thinking processes are also limited. Furthermore, a series of tests were carried out to prove the research hypothesis or the effectiveness of the independent variables to the dependent variable. The test started with the prerequisite test, the N-gain test, and then the one-tailed proper hypothesis test.

**Prerequisite Test**

The data normality test was carried out by the Kolmogorov Smirnov test on two groups of data on differences in pretest-posttest scores (gain scores) for students' critical thinking abilities in the experimental class and control class with the help of the IBM SPSS Statistics 23 application. The test results showed a value of 0.200 (> 0.05 ), meaning that both data groups are normally distributed. Once it is known that the two groups of data are normally distributed, the homogeneity test is carried out with the $F_{test}$. The results of the calculation of $F_{count}$ show that it is 1.207 and $F_{tabel}$ is 1.828, so according to the applicable provisions, namely $F_{count}<F_{tabel}$ (1.207<1.828), it is known that the data is homogeneous.

**N-Gain Test**

Normalized Gain (N-gain) test on the difference in pretest-posttest values in the control class and experimental class with the help of the IBM SPSS Statistics 23 application. The N-gain test results can show the model's considerable influence in the normalized increase value of students' critical thinking ability before and after treatment in the two study classes. The results of the N-gain test can be seen in Table 2.

**Table 2**. N-gain Test Results

| Class Group | N-gain value | Criteria |
|---|---|---|
| Experiment | 0.417 | Currently |
| Control | 0.246 | Low |

Table 2 shows that the N-gain value in the class with the application of the PjBL-STEM model is 0.417 and is categorized in the medium criteria. In contrast, the class with the PjBL model has an N-gain value of 0.246 and is categorized in the low criteria.

**Hypothesis Test**

After the data is said to be normally distributed and homogeneous, the one-tailed t-test is continued using the independent sample t-test. The test was carried out using the IBM SPSS Statistics 23 application with a significant level of 5% (0.05). The results of hypothesis testing can be seen in Table 3


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**Table 3**. Statistical Description of Research Data

| Data Type | df | Average difference (tcount) | *Sig (2-tailed) Pvalue = ½ sig* | Decision |
|---|---|---|---|---|
| The difference pretest-posttest score (gain score) | 61 | 4,012 | 0.000 | H0 is rejected |

Table 3 results show a $t_{count}$ of 4.012 and a $P_{value}$ (sig 1-tailed) of 0.000. If it is known that the ttable for the one-tailed test is 1.669, then it is known that 4.012> 1.669 and 0.000 <0.05. The result indicates that the $t_{count} > t_{table}$ and $P_{value}$ < sig (0.05), then H0 is rejected, and Ha is accepted. So the conclusion of testing the hypothesis is that the effect of the PjBL-STEM model on students' critical thinking ability in junior high school science learning is greater than the PjBL model. These results are the same as Dywan & Airlanda research (2020), which says that the PjBL-STEM model is said to be effective (positive influence) in improving students' critical thinking ability. Then these results have also proven previous research conducted by Rahardhian (2022) dan Sri et al. (2021), who said that there was a significant influence of the application of the PjBL-STEM model on students' critical thinking abilities.

When viewed from the results of observations of syntax implementation in the two research classes, it is known that the experimental and control classes received an implementation value of 100. Hasil tersebut menunjukkan bahwa siswa dapat meningkatkan kemampuan berpikir kritisnya setelah melakukan kegiatan pada setiap tahapan model PjBL-STEM dan model PjBL. It's just that, based on the results of hypothesis testing, the influence of the model on the critical thinking skills of students in classes using the PjBL-STEM model is more significant than the class using the PjBL model. The difference in the effect of applying a meaningful model in the experimental class and the control class is inseparable from the role of the characteristics of the two models, including the activities in the syntactic stages of the two research classes (Amelia et al., 2021; Fitriyani, Toto, & Erlin, 2020). One activity that differentiates and can develop critical thinking skills influences the model's effectiveness is the existence of redesign activities or engineering aspects of the PjBL-STEM model. In classes with the PjBL model, other than student projects that the teacher has directed, there are no redesign activities at this model stage that train students to develop and improve their project designs so that the products made can solve the problems presented. That is what makes students in the experimental class more able to develop their critical thinking skills.

## CONCLUSION

Through the description of the results and discussion, that is known that the PjBL-STEM model can increase the average score of students' critical thinking ability in science learning, including each indicator, interpretation, analysis, inference, evaluation, explanation, and self-regulation. The results of the t-test on the right side on the difference between the pretest-posttest scores of students' critical thinking ability show $t_{count}>t_{table}$ with $P_{value}$ 0.000 and experimental class had an N-Gain value of 0.417, while the control class was 0.246. Therefore, it can be proven that the effect of the PjBL-STEM model on students' critical thinking ability in science learning is more significant than the PjBL model. So, this study implemented that the Project-Based Learning model integrated with STEM can be an option and learning innovation to further increase students' critical thinking ability.

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