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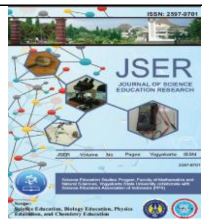

Building Students' Critical Thinking Abilities Through Project-Based Learning Models on Energy Transformation Material

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Abstract

The research examined the issue of low critical thinking skills of students in Natural and Social Sciences (IPAS), which is linked to their low engagement and involvement in learning activities. The study aimed to assess the effect of the Project-Based Learning model on improving students' critical thinking skills, particularly in the context of energy transformation topics. The research used a Quasi-Experimental Design, by following the Nonequivalent Posttest Only Control Group Design. The population were all students at SDN Dukuh Menanggal 1 Surabaya for the 2023/2024 school year. Sample selection technique used a purposive sampling, which selected 30 students from class IV-A and 30 students from class IV-B. The research showed that the post-test scores in the experimental class were higher, with an average score of 87.4. Meanwhile, the control class obtained a score of 71.9. Inferential analysis was conducted using SPSS 26 to test for normality, homogeneity, and hypotheses. The normality and homogeneity tests indicated that the distributions of both classes are normal and homogeneous. Based on the hypothesis test using the Independent Sample T-test, a significance level of 0.000 was obtained, which means that the Project-Based Learning model has a significant effect on developing students' critical thinking abilities in IPAS on the topic of energy transformation.

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INTRODUCTION

Education is inseparable from man and his life because it is, in fact, a conscious and planned effort to maximize human resources in a social life. Education is also an individual effort to develop self-quality because, with education, we can help development at every age (Nuraeni, 2022). In the 21st century, as it is today, the world is evolving very rapidly and dynamically. The various aspects of life are evolving rapidly to meet the demands of life. As a result, growth and technological progress grow and develop fast, such as the advancements in growth and development within the field of education.

In the growth and development of the world of education today, students must have high-level thinking skills, such as critical thinking. It is an ability to think actively and systematically in analyzing, evaluating, arguing, and interpreting information (Yuliastrin et al., 2023). This opinion is in line with Facione (in Suteja & Setiawan, 2022) that critical thinking ability is a set of active and skilled cognitive abilities in conceptualizing, applying concepts, analyzing, synthesizing, and evaluating information obtained from observation, reflection, experience, reasoning, or communication as a guide to determine attitudes or actions. Critical thinking is also an ability that must be trained in students as a provision for the future because by thinking, a person will think about what to believe and how to act (Wahyuddin et al., 2022). Therefore, in this critical thinking ability, students are required to analyze and conclude the received information. As the result, students can distinguish good and bad information, and make decisions on the information through critical thinking. In other words, this critical thinking requires students to improve their ability to analyze a problem, find a solution to the problem, and provide new ideas, strategies, and tactics to provide a new picture of solving a problem. Therefore, students urgently need to develop and train this ability, especially in learning.

A subject in the school that may improve students' critical thinking skills is learning Natural Sciences (IPA). However, today, this subject integrated into the learning of Natural and Social Sciences (IPAS). Learning IPAS is a science that studies living and dead things in the universe and their interaction, as well as the study of human life as an individual and as a social being that interacts with its environment (Safira, 2023). Therefore, learning IPAS in elementary school is expected to be a way for students to learn about themselves, the environment and its environment, and the prospects for further development in application in everyday life (Suhelayanti et al., 2023). Thus, this IPAS learning directs the student to demonstrate effectively through experiment or observation following the concepts he is studying so that it can help students to be able to think critically about problem-solving in particular in the learning of IPAS. Therefore, this is the reason of the important for this critical thinking ability to be built continuously as an effort to encourage the student to do logical problem-solving.

However, a few of the learning of IPAS in Indonesia directs students toward improving their critical thinking ability. But, it is still on low-level cognitive learning outcomes. As a result, Indonesian education is relatively low quality (Fitriyah & Ramadani, 2021). This is shown by previous surveys, including the 2022 Programme for International Student Assessment (PISA) study, that Indonesia's science literacy score is 383, placing it 67th out of 81 countries (OECD, 2023). The study gives an insight that critical thinking skills of students are still underdeveloped.

The low critical thinking ability also occurred in the students of the fourth grade at SDN Dukuh Menanggal 1 Surabaya, where this skills is also not well developed. An argue that the students' critical thinking skills during their study of IPAS material energy transformation remain inadequate. The student's low critical thinking ability is evident from the lack of student activity in the process of pursuit. Also, this is evident from the student's inability to express opinions even though the educators allow delivering opinions at the learning activities. Moreover, the learning test results of IPAS energy transformations around us are still below the minimum qualification criteria of elementary school students. Supported by Mawardi & Sari (2019), a student's low level of critical thinking ability in IPA learning is caused by students' passive behavior. So, when educators give questions, only a few students answer questions. In addition, other research with different subjects has shown that, on the material of energy transformation around us, students tend to have poor understanding. It shows the lack of student activity in the learning process. And, the low level of students in thinking in concrete by associating the concept of energy material in everyday life makes this material very difficult to build the students speak and think critically (Rani & Mujianto, 2023).

Based on these problems, there is a need for a learning model that can build students' critical thinking skills, especially in IPAS learning on energy transformation material. One of the learning models currently believed to be able to build students' ability to think critically is the Project-Based Learning model. It is a learning process that is student-centered and provides meaningful learning experiences for students (Rahmania, 2021). Supported by Indrayana & Susilowati (2020), state that the Project-Based Learning model is carried out collaboratively in heterogeneous groups, focused on questions that direct students to use concepts or principles through an experience. Therefore, this learning model is believed to improve the students' critical thinking skills, especially in IPAS learning because the steps in the model motivate students to be actively involved in the problem solving process, design an idea, and provide opportunities. As the result, students construct their thinking skills to produce a valuable product or work (Mahdarani et al., 2023). Thus, using this Project-Based Learning model, students are trained to analyze problems, explore, collect and interpret information, and evaluate project work related to the investigated problem (Boss & Krauss, 2022). In addition, students are allowed to explore their abilities and skills according to their plans (Cintang et al., 2018). Therefore, it is expected that using the Project-Based Learning model in IPAS learning will be more meaningful because students can gain experience directly without having to guess the material to be learned (Syaravina et al., 2023).

Many researchers have conducted research on project-based learning (PBL). First, Putriyanti et al. (2021) showed that the Project-Based Learning model succeeded in improving students' critical thinking skills in grade V elementary school.

Second, Nadiyah & Tirtoni (2023) found out that the Project-based Learning model has successfully improved students' critical thinking skills in the Merdeka curriculum. Third, Winarti et al. (2022) showed that Project-Based Learning improve the critical thinking skills of third grade elementary school students. This current research is different with previous research in terms of learning materials and projects implemented. Therefore, the study focused on the impact of the Project-Based Learning model in building students' critical thinking skills on energy transformation material.

RESEARCH METHOD

The type of research was experimental quantitative research. This method involved investigating the effect of a specific treatment on another variable under controlled conditions (Hikmawati, 2020). This research employed a quasi-experimental design. Although this design incorporates a control group, it does not fully account for external variables that could affect the experiment results (Sugiyono, 2013). Hence, this study used a nonequivalent posttest-only control group design, involving two pre-existing groups that were not randomly assigned. The design features two distinct groups: the experimental group (which receives the treatment) and the control group (which does not). Table 1 shows the nonequivalent posttest-only control group design.

Table 1. Type of *Nonequivalent Posttest Only Control Group Design*

Class	*Treatment*	*Posttest*
E	X	O_1
K	-	O_2

Description:

E : Experimental class
K : Control class

X : Treatment, implementation of teaching and learning activities with the Project-Based Learning model
O_1 : Posttest learning results by using Project-Based Learning model
O_2 : Posttest learning results by using conventional model

This research involved two groups- the experimental and the control. These groups are distinguished by the different treatments applied during the learning process. The experimental group (E) is given the treatment (X) through the application of the Project-Based Learning model, whereas the control group (K) does not receive any treatment. To assess the impact of the Project-Based Learning model, the posttest results of the experimental group (O_1) are compared with those of the control group (O_2), which aims to understand how the model affects students' critical thinking skills in the context of energy transformation materials.

The population was all students of SDN Dukuh Menanggal 1 Surabaya, which was 60 students. One class played as the experimental group. Meanwhile, another class played as the control group. Each class group consisted of 30 students. The samples were selected using purposive sampling techniques (Sugiyono, 2013). A particular consideration in this study is the availability of preliminary data, carried out by researchers when conducting pre-research classes with low critical thinking levels are used as experimental classes, and classes with higher critical-thinking abilities are used as control classes. Class group of IV-A denoted the experimental class, while class group of IV-B represented the control class.

Data collection employed critical thinking assessment tools, specifically essay tests comprising 10 questions with specific indicators according to Ennis (in Maulana, 2017) that give a simple explanation with a total of 3 questions, conclude with a maximum of 3 issues, give further explanations with a number of 3 problems, and set strategies and tactics with the number of 1 question. As for these tests, the posttest were conducted after being treated. Using this test instrument in data collection aims to test students' ability to think critically when learning the IPAS energy transformation material around them.

This research data analysis technique used inferential statistical techniques, which aims to process research data, namely posstest scores with the aim of knowing the difference in improving students' critical thinking skills using SPSS software version 26. Before hypothesis test, two prerequisite tests were carried out, normality and the homogeneity. Those test aims to determine whether the data is normally distributed or not and homogeneous or not.

RESULT AND DISCUSSION

The findings of the research conducted on the topic of energy transformation in Natural and Social Sciences (IPAS) in Class IV at SDN Dukuh Menanggal 1 Surabaya, using the Project-Based Learning model, were supported by the processed and analyzed test data. The test consisted of 10 essay questions, focused on critical thinking indicators according to Ennis (in Maulana, 2017) that give a simple explanation, conclude, give further explanations, and set strategies and tactics. Table 2 presents the results of the critical thinking test for both the experimental and control classes.

Table 2. Research Results Data

Statistics	Research Class	
	Experiment	Control
N	30	30
Minimun	78	60
Maximum	100	90
Mean	87.4	71.9
Std. Deviation	6.651	8.470

Table 2 shows a significant difference in results between the experimental class and the control class. This difference is important for validating and supporting the hypothesis. The next step involves analyzing the data using SPSS version 26. Before the analysis, preliminary tests such as normality and homogeneity carried out. The normality test assesses whether the data follows a normal distribution. In this study, a significance value above 0.05 indicates that the data is normally distributed, while a value below 0.05 suggests a departure from normality. The results of the posttest normality test are presented in Table 3.

Table 3. Normality Test Results for Posttest Scores for Critical Thinking Abilities

	Tests of Normality			
	Class	***Shapiro-Wilk***		
		Statistic	**df**	**Sig.**
Critical Thinking Abilities	Experiment	.943	30	.110
	Control	.952	30	.186

According to Table 3, the normality test results for the posttest data show a significance value of 0.110 (> 0.05) for the experimental class and 0.186 (> 0.05) for the control class. These results indicate that the data in both groups follows a normal distribution, as the significance values above 0.05. Therefore, the normality test confirms that both classes have normally distributed data. The next step is the homogeneity test, which determines whether the data from the two groups are homogeneous (similar). In this study, homogeneity is indicated by a significance value above 0.05. Meanwhile, a value below 0.05 suggests a poor of homogeneity. The resultsof the homogeneity test are presented in Table 4.

Table 4. Homogenity Test Results for Posttest Scores for Critical Thinking Abilities

Test of Homogeneity of Variances					
	Levene Statistic	**df1**	**df2**	**Sig.**	**Conclusion**
Critical Thinking Abilities	1.549	1	58	.218	Homogen

The homogeneity test was carried out with a significance level of α = 0.05, producing a significance value of 0.218 (> 0.05). This suggests that the variability in the post-test data between the experimental and control classes is consistent or homogeneous, which continue to further analysis. The purpose of this test was to evaluate the effect of the Project-Based Learning model on enhancing students' critical thinking skills in energy transformation materials.

The conclusion from hypothesis testing is, as follows: When the significance value (Sig) is less than 0.05, the null hypothesis (Ho) is rejected and the alternative hypothesis (Ha) is accepted. In contrast, if the significance value is greater than 0.05, Ho is accepted and Ha is rejected. The hypothesis test results are presented in Table 5.

Table 5. Hypothesis Test Results for Posttest

		Independent Samples Test						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Critical Thinking Abilities	Equal variances assumed	1.549	.218	7.848	58	.000	15.433	1.966

The hypothesis test results in Table 5 show a two-tailed significance (Sig) value of 0.000, which is below 0.05. As a result, the null hypothesis (Ho) is rejected, and the alternative hypothesis (Ha) is accepted. This suggests that the Project-Based Learning model significantly affects the development of student's critical thinking skills in the context of energy transformation materials.

T-Test hypothesis showed that the Project-Based Learning model significantly improves students' critical thinking skills in energy transformation materials. This effect is attributed to the structured use of Project-Based Learning methods during the educational process, which fosters increased student engagement. Consequently, students' critical thinking abilities improve. It has similar finding with previous research that the Project-Based Learning model enhances students' critical thinking skills, as it requires critical thinking for tasks such as expressing opinions, project planning, design, and presentation (Putriyanti et al., 2021). Thus, by applying the Project-Based Learning model, students are encouraged to participate in discussions about the issues emerging from the experimental worksheets.

The first step in Project-Based Learning is to identify basic questions that assign students to solve a problem (Haryani et al., 2018). At this stage, the educator asks basic questions about the material of energy transformation around us. Some of these questions are used by educators to open students' thoughts about the learning. The basic questioning activities can help students be more active in asking and answering questions and wanting to know what they will learn. These questioning activities improve students' critical thinking skills because these activities require students to ask questions, provide arguments for questions and can provide deductive or inductive conclusions to the problems (Hikmah et al., 2016). In line with the opinion of Wardani & Fiorintina (2023) that students can develop their critical thinking skills and achieve a deeper comprehension of the material by formulating and addressing difficult questions. This process encourages them to analyze, evaluate, and synthesize information more effectively, leading to a richer understanding of the material of learning.

The second step is to prepare a project plan. The project's plan activities are carried out in collaboration between educators and students. At this stage, educators and students are planning projects related to energy transformation experiments. The educator gives LKPD-related trials of thin orange batteries and spiral paper and the students together with their group practice of the experimental activities that have been focused in the LKPD. According to Fiorintina et al. (2023), working with LKPD can activate students in developing critical thinking skills such as making deductions, inductions, and decisions. Thus, this critical thinking ability prioritizes the ability to formulate, define, argue and conclude in solving a problem (Amanda et al., 2018).

In this third step, students and educators collaboratively schedule the completion of a project. The activities include the creation of timelines and deadlines to complete the project. Therefore, the time for the implementation of the project should be clear, and the student should be given instructions on managing the availability time. A student's project takes a long time in its execution and implementation process, so the educator asks the student to complete the project on time according to a previously agreed schedule. Scheduling project completion activities can develop students' critical thinking skills because students must be able to determine strategies and tactics or an action for project completion. Following Sofiah's (2015) opinion, states that, at the time of project completion, scheduling activities can improve students' critical thinking skills when determining project completion strategies and tactics.

The fourth step is to monitor project completion progress. At this stage, the educator monitors the student's progress and facilitates the student during the project creation process. At this stage, students can also describe problems or obstacles encountered during project activities. With students telling obstacles or problems encounters make students think critically in asking and answering questions, concluding, and identifying assumptions. With this monitoring activity, educators have to record all the student activities during the implementation of the project. So, students are more guided, targeted, and accurate at project creation (Izzati, 2014).

The fifth step is to test the results. Learning using this Project-Based Learning model directs students to produce a product that is through a group discussion report and experimental results of energy transformation around us, such as moving spiral paper and thin orange batteries that will later be presented in front of the classroom. Here, each alternate group communicates or presents its observations of the energy transformation around us, and the non-presentative group is allowed to give its opinion. These activities encourage students to engage in critical thinking by expressing opinions, drawing conclusions, making observations, and analyzing the results of their observations. According to Noviyanti (2011), when engaging in communication, such as discussing, expressing opinions, and understanding social issues, students can develop a deeper comprehension of the learning material.

The final step in Project-Based Learning is to evaluate the experience. In this phase, educators and students carry out activities of reflection on the results of the work, either individually or in a group. Educators, through evaluation, provide students with the chance to share their thoughts on the learning process. These activities encourage students to think critically, draw conclusions, and respond to questions about the material covered. This approach helps students become more confident and engaged participants in their learning, thereby improving their critical thinking skills. An indicator developed with Ennis (in Maulana, 2017) is to make a conclusion that includes considering deduction and induction as well as considering the outcome. Thus, the learning process using the Project-Based Learning model influences in building students' critical thinking skills in the IPAS subject of energy transformation material.

Based on the critical thinking ability test instrument is aimed at providing assessment based on critical thinking indicators, which are elementary clarification, advanced clarification, inference, and strategy and tactics. The table 6 shows the results of the achievement of critical thinking indicators.

Table 6. Percentage Results of Critical Thinking Ability Test

No	Indicators of Critical Thinking Abilities	Percentage (%)	Category
1	Elementary Clarification	81	Very Critical
2	Advance Clarification	92	Very Critical
3	Inference	88	Very Critical
4	Strategy and Tactics	92	Very Critical

Based on the table of the percentage results of the critical thinking ability test, shows that the first indicator of critical thinking ability is elementary clarification. The percentage results of this indicator on the experimental class posttest obtained a value of 81% with a very critical category. This category is supported by Fitriani (2022) who states that the indicators on the aspect of providing simple explanations have an average score in the high category. This achievement is seen when students answer the question and can analyze and understand well the meaning of the question. Because, students in the experimental class in project learning have a stage of determining fundamental questions. Then, when questions are answered, students can indirectly see various main elements as well as various principles in a discipline they are studying (Haryani et al., 2018). In addition, students in the experimental class are trained to discuss project planning so that they are used to asking and answering questions.

The second indicator is to provide further explanation. This indicator in the experimental class posttest obtained a percentage of 92% in a very critical category because it can define terms and definitions and identify assumptions. This is shown by the ability of students to define terms and identify assumptions in energy transformation events when students answer questions. Then, students can reason well about energy transformation events that occur in everyday life. In line with Kurniahtunnisa et al. (2016), states that indicators in the aspect of providing further explanation have an average score in the critical category because students are required to read the problem text and discuss and find solutions to existing problems. By these activities, students can develop the ability to identify terms and definitions and identify assumptions. The ability to define terms and identify assumptions is an indicator of the aspect of providing further explanation (Ennis in Maulana, 2017).

The third indicator of critical thinking skills is inference. The results of this indicator on the experimental class posttest obtained a percentage value of 88% with a very critical category. This inference indicator has a high percentage because project-based learning in the experimental class trains students to draw conclusions from the discussed problems. Supported by Zahroh (2020), the inference aspect indicator has the highest average score because the experimental class is used to concluding from material or events experienced in practicum. Thus, through concluding activities at the end of practicum or learning, it increase the concluding aspect of students' critical thinking skills. Paul and Helder (in Kurniahtunnisa et al., 2016) state one of the characteristics of someone who has critical thinking skills is that they can conclude well.

The percentage results after the implementation of project learning shows that the indicators of providing further explanation and organizing strategies and tactics obtained the same results of 92% with a very critical category as students can evaluate appropriately. So, students find it easier to conclude a problem or idea, prove an answer is right or wrong, and validate a solution that might be used in the activity of solving a problem encountered in the learning process. This might occur because, through learning the Project-Based Learning model in the experimental class, students are trained to make decisions from the problems (Zahroh, 2020). Supported by the opinion of Indratno et al. (2018), that learning with the Project-Based Learning model can make students active in terms of making decisions, designing solutions, and being responsible for finding and managing information. Therefore, if teachers deliberately and continuously train students' higher-order thinking skills, for example, using real-world problems, encouraging class discussions, and conducting investigations, they may develop students' critical thinking skills (Miri et al., 2007).

Through the presentation of the percentage results of the critical thinking ability indicators, it concluded that the provision of treatment in the experimental group through the application of the Project-Based Learning model can build students' critical thinking skills in the IPAS material of energy transformation.

CONCLUSION

Based on the finding and discussion, it concluded that the application of the Project-Based Learning model has a good impact on building students' critical thinking abilities in IPAS learning on energy transformation material around us. This can be proven by the students' enthusiasm during the project-based learning process and the increase in students' critical thinking abilities in the learning process.

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