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Strengthening Pancasila Student Competencies through a Mini Hydropower Project in Science Education to Support Sustainable Development Goals (SDGs)

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Abstract— *Strengthening students' competencies, including critical thinking and creativity, is an essential part of implementing the Pancasila Student Profile within the Merdeka Curriculum. One instructional approach that can support the development of these competencies is Project-Based Learning (PjBL). This study aims to analyze the effect of implementing Project-Based Learning through a mini hydropower model project on students' critical thinking and creativity in science learning on renewable energy topics. The study employed a quantitative approach with a quasi-experimental design of the non-equivalent control group type. The research was conducted in the odd semester of 2025 with ninth-grade students at a junior high school in Mataram City. The sample consisted of two classes, namely an experimental class of 31 students and a control class of 29 students. The research instrument was an essay test consisting of 10 items, including 5 items to measure critical thinking and 5 items to measure creativity. The data were analyzed using descriptive statistics and one-way MANOVA. The results showed that the mean scores of students' critical thinking and creativity in the experimental class were higher than those in the control class. The MANOVA results indicated a significance value of less than 0.05, demonstrating that the implementation of Project-Based Learning through the mini hydropower project had a significant effect on students' critical thinking and creativity. Project-based learning in renewable energy topics not only enhances higher-order thinking skills but also supports the strengthening of Pancasila Student competencies and is relevant to achieving the Sustainable Development Goals, particularly in quality education and clean, sustainable energy.*

Keywords— Project-Based Learning, Renewable Energy, Mini Hydropower Model, Critical Thinking, Creativity, Pancasila Student Profile.
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1. Introduction

The development of science and technology in the 21st century requires the education system to produce human resources who possess critical thinking, creativity, and problem-solving skills to address real-life challenges. Increasingly complex global challenges demand that students not only have conceptual knowledge but also Higher Order Thinking Skills that enable them to analyze problems and generate innovative solutions [1]. Therefore, the learning process needs to be designed contextually and oriented toward the development of 21st-century competencies so that students can adapt to the rapid advancement of science, technology, and social change [2].

Efforts to improve the quality of education are aligned with the global agenda of the Sustainable Development Goals (SDGs), particularly Goal 4, Quality Education, which emphasizes the importance of quality education in enhancing critical thinking, creativity, and problem-solving skills. Education is not only a means of knowledge transfer but also a process of character and

competency development to enable students to contribute to sustainable development [3]. Therefore, learning should be designed to provide meaningful experiences that are relevant to real-world problems [4].

In the Indonesian context, the development of student competencies is directed through the implementation of the Merdeka Curriculum, which emphasizes character building and competency development through the Pancasila Student Profile. This profile includes six key dimensions, among which critical thinking and creativity are essential competencies for facing future global challenges [5]. Critical thinking enables students to objectively analyze information, evaluate problems, and make logical decisions, while creativity encourages them to generate innovative ideas and solutions in everyday life [6].

One global issue relevant to science learning is the problem of energy. Currently, most of the world's energy needs still depend on non-renewable sources such as oil, coal, and natural gas. This dependence not only leads to future energy limitations but also causes environmental problems such as pollution and climate change [7]. Therefore, it is necessary to increase awareness and understanding among younger generations about the importance of renewable energy as a sustainable and environmentally friendly alternative [8].

Renewable energy is also a key focus in the Sustainable Development Goals, particularly Goal 7, Affordable and Clean Energy, which emphasizes access to clean, affordable, and sustainable energy for all. Education plays a strategic role in supporting this goal by introducing students to renewable energy concepts and encouraging innovation in utilizing environmentally friendly energy sources [9]. Through contextual learning, students can understand how energy concepts are applied in real life to support sustainable development [10].

One of the most promising renewable energy sources is hydropower. Water energy is sustainable, environmentally friendly, and can be utilized at various scales. In science education, hydropower concepts can serve as engaging learning media that integrate conceptual understanding with practical skills and problem-solving abilities [11]. Through activities such as building a mini hydropower model, students can directly understand the transformation of potential energy into electrical energy.

To ensure meaningful learning in renewable energy, an instructional model that actively involves students is required. One suitable model is Project-Based Learning (PjBL), which emphasizes project completion through exploration, investigation, and the creation of tangible products [12]. Through this approach, students not only understand concepts theoretically but also develop critical thinking and creativity through designing and producing projects [13].

The implementation of Project-Based Learning through a mini hydropower project allows students to analyze energy-related problems, design solutions, and evaluate experimental results. This process encourages critical thinking in understanding energy concepts and their applications [14]. Additionally, designing and building the mini hydropower model fosters creativity by encouraging innovative ideas in design and mechanisms [15].

Previous studies have shown that Project-Based Learning can enhance students' critical thinking and creativity in science learning. However, studies that specifically integrate renewable energy learning through mini hydropower projects with the development of the Pancasila Student Profile are still limited [16]. Furthermore, research examining the simultaneous effect of project-based learning on critical thinking and creativity in renewable energy contexts remains scarce [17].

Based on this, the novelty of this study lies in the integration of Project-Based Learning, renewable energy education through a mini hydropower project, and the development of Pancasila Student competencies focusing on critical thinking and creativity. This approach not only supports the implementation of the Merdeka Curriculum but also contributes to achieving sustainable development goals, particularly SDG 4 (Quality Education) and SDG 7 (Affordable and Clean Energy), through contextual and project-based science learning [18]. Therefore, this study aims to examine how the implementation of Project-Based Learning through a mini hydropower project contributes to developing students' critical thinking and creativity as part of the Pancasila Student Profile in renewable energy learning [19].

2. Method

This study employed a quantitative approach using a quasi-experimental method to analyze the effect of implementing a learning model on students' competencies. The research design used was a non-equivalent control group design. This design involved two groups with relatively similar characteristics, namely the experimental group and the control group. The experimental group received treatment in the form of learning using the Project-Based Learning model through a mini hydropower model project, while the control group received conventional instruction. Both groups were given a post-test after the learning process to measure students' critical thinking and creativity [20].

The study was conducted in the odd semester of 2025 at SMP Negeri 16 Mataram, West Nusa Tenggara. The research subjects were ninth-grade students who studied renewable energy in science learning. The population consisted of all ninth-grade students at the school. The sampling technique used was cluster random sampling by selecting two classes from the available classes. Based on this technique, two sample classes were obtained, one as the experimental class consisting of 31 students and one as the control class consisting of 29 students.

The independent variable in this study was the Project-Based Learning model implemented through a mini hydropower model project. The dependent variables were Pancasila Student competencies, including critical thinking and creativity. Critical thinking was measured through indicators such as identifying energy-related problems, analyzing energy transformation processes in hydropower systems, relating energy concepts to turbine mechanisms, evaluating the design of the model, and drawing conclusions based on experimental results. Creativity was measured through indicators such as generating ideas for mini hydropower designs, developing turbine or driving system designs, selecting appropriate materials for construction, proposing innovations in the power generation system, and explaining the steps in constructing the mini hydropower model. The indicators of Pancasila students' critical thinking competency are presented in Table 1.

Table 1. Indicators of Pancasila Students' Critical Thinking Competency

No	Critical Thinking Indicators	Type of Ability
1	Identifying problems related to energy limitations and the importance of renewable energy	Students are able to explain energy-related problems and the need for alternative energy
2	Analyzing the principles of energy transformation in hydropower plants	Students are able to explain the transformation of energy from water potential energy into electrical energy
3	Relating the concepts of force, motion, and energy in a mini hydropower turbine system	Students are able to explain the relationship between physics concepts in the mechanism of the device
4	Evaluating the design of the mini hydropower model	Students are able to assess the strengths and weaknesses of the design
5	Drawing conclusions based on the results of the mini hydropower experiment	Students are able to conclude the effectiveness of the model in generating electrical energy

The indicators of Pancasila students' creative thinking competency can be seen in Table 2.

Table 2. Indicators of Pancasila Students' Creativity Thinking Competency

No	Creative Thinking Indicators	Type of Ability
1	Generating ideas for a mini hydropower model design	Students are able to propose design ideas for a hydropower-based electricity generator
2	Developing turbine designs or water rotation systems	Students are able to design turbine shapes or generator driving mechanisms
3	Proposing the use of alternative materials or tools	Students are able to select or modify materials that can be used in constructing the model
4	Developing innovations in the power generation system	Students are able to modify the design to make the system more effective
5	Presenting the mini hydropower model design systematically	Students are able to describe or explain the design clearly and logically

The research instrument used was a thinking skills test in the form of essay questions developed based on the measured competency indicators. The instrument consisted of ten essay items, including five items to measure critical thinking skills and five items to measure students' creativity. Data collection was carried out through a written test to assess students' critical thinking and creativity after the learning process.

Data analysis was conducted using statistical software through several stages. The first stage was descriptive statistical analysis to determine the mean, standard deviation, minimum, and maximum scores of students' critical thinking and creativity in the experimental and control classes. The next stage involved testing the assumptions of analysis, including tests of normality, homogeneity of variance, homogeneity of covariance matrices, and linearity to determine the linear relationship between the dependent variables.

After all assumptions were met, hypothesis testing was conducted using one-way Multivariate Analysis of Variance (MANOVA). This analysis was used to determine whether there were significant differences between the experimental and control classes across the two dependent variables simultaneously, namely students' critical thinking and creativity. The decision was based on the significance value of the multivariate statistics. If the significance value was less than 0.05, it could be concluded that the implementation of Project-Based Learning through a mini hydropower model project had a significant effect on students' critical thinking and creativity [21].

3. Result and Discussion

Results

Before the instrument was implemented in the learning intervention, its quality was first evaluated to ensure that each item was able to accurately and consistently measure the intended constructs. The empirical validity of the instrument was examined using the Pearson product-moment correlation coefficient on 30 students. This analysis aimed to determine the degree of correlation between the score of each item and the total instrument score. An item was considered valid if its item-total correlation coefficient was higher than the critical r-value at the 5% significance level. The results of the empirical validity analysis for the 10 items measuring critical thinking and creativity competencies are presented in Table 3. The analysis results showed that the item-total correlation coefficients for the 10 items ranged from 0.704 to 0.949, which were higher than the r-table value of 0.361 at the 5% significance level. In addition, all items showed significance values of $p < 0.05$. Therefore, all instrument items were declared valid and appropriate for use in the research data collection stage.

Table 3. Empirical Validity Results of Critical Thinking and Creativity Instrument Items

No.	Item	Calculated r-value	Critical r-value	Sig.	Decision
1	Item 1	0.949	0.361	0.000	Valid
2	Item 2	0.830	0.361	0.000	Valid
3	Item 3	0.704	0.361	0.000	Valid
4	Item 4	0.838	0.361	0.000	Valid
5	Item 5	0.816	0.361	0.000	Valid
6	Item 6	0.872	0.361	0.000	Valid
7	Item 7	0.801	0.361	0.000	Valid
8	Item 8	0.744	0.361	0.000	Valid
9	Item 9	0.811	0.361	0.000	Valid
10	Item 10	0.849	0.361	0.000	Valid

After all instrument items were declared valid through empirical validity testing, the next step was reliability testing to determine the internal consistency of the instrument. Reliability analysis was conducted using Cronbach's Alpha based on responses from 30 students. This analysis aimed to examine the consistency of the 10 essay items in measuring students' critical thinking and creativity competencies within the mini hydropower project activities. An instrument is generally considered reliable if the Cronbach's Alpha coefficient exceeds 0.70. The results of the reliability analysis are presented in Table 4.

Table 4. Reliability Test Results of the Research Instrument

Cronbach's Alpha	Number of Items	Reliability Category
0.947	10	Very High

Based on Table 4, the instrument obtained a Cronbach's Alpha coefficient of 0.947 across 10 items. This value is substantially higher than the minimum acceptable threshold of 0.70, indicating that the instrument has very high internal consistency. These results confirm that the instrument is reliable and appropriate for use in data collection. The high reliability coefficient also indicates that the items consistently measure the intended constructs of critical thinking and creativity.

To further examine the contribution of each item to the overall reliability of the instrument, an item-level analysis was performed using *Corrected Item-Total Correlation* and *Cronbach's Alpha if Item Deleted*. The *Corrected Item-Total Correlation* indicates the extent to which each item correlates with the total instrument score, while *Cronbach's Alpha if Item Deleted* evaluates whether removing an item would improve the reliability coefficient. The detailed item-total statistics are presented in Table 5.

Table 5. Item-Total Statistics of the Research Instrument

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Item 1	29.2667	29.099	0.933	0.934
Item 2	29.0333	31.068	0.789	0.941
Item 3	29.1333	32.051	0.636	0.947
Item 4	29.1667	30.557	0.795	0.941
Item 5	29.1667	30.764	0.768	0.942
Item 6	29.1000	30.438	0.838	0.939
Item 7	29.1667	30.902	0.750	0.943
Item 8	29.0333	31.826	0.685	0.945
Item 9	29.0000	31.172	0.765	0.942
Item 10	29.2333	30.323	0.807	0.940

As shown in Table 5, the *Corrected Item-Total Correlation* values ranged from 0.636 to 0.933, indicating that all items had strong positive correlations with the total instrument score. All correlation values exceeded the minimum recommended value of 0.30, suggesting that each item contributed meaningfully to the measurement of the intended constructs. The highest correlation was found in Item 1 (0.933), while the lowest was observed in Item 3 (0.636); however, both values remained within the acceptable range. Furthermore, the *Cronbach's Alpha if Item Deleted* values ranged from 0.934 to 0.947. Since deleting any item did not produce a substantial increase in the overall reliability coefficient, all items were retained. These findings indicate that each item contributes positively to the overall consistency of the instrument, confirming that all 10 items are suitable for measuring students' critical thinking and creativity competencies in the mini hydropower project.

Based on the data in Figure 1, Pancasila Student competencies in the experimental class, which include critical thinking and creative thinking, show relatively high and stable performance. Students' critical thinking scores range from 76 to 90, with the lowest score being 76 and the highest reaching 90. Meanwhile, creative thinking scores range from 78 to 90, with the lowest score being 78 and the highest also reaching 90. In general, creative thinking scores tend to be slightly higher than critical thinking scores for most students. This indicates that the implementation of project-based learning through the development of a mini hydropower model is able to optimally enhance Pancasila Student competencies, particularly in the aspects of critical and creative thinking.

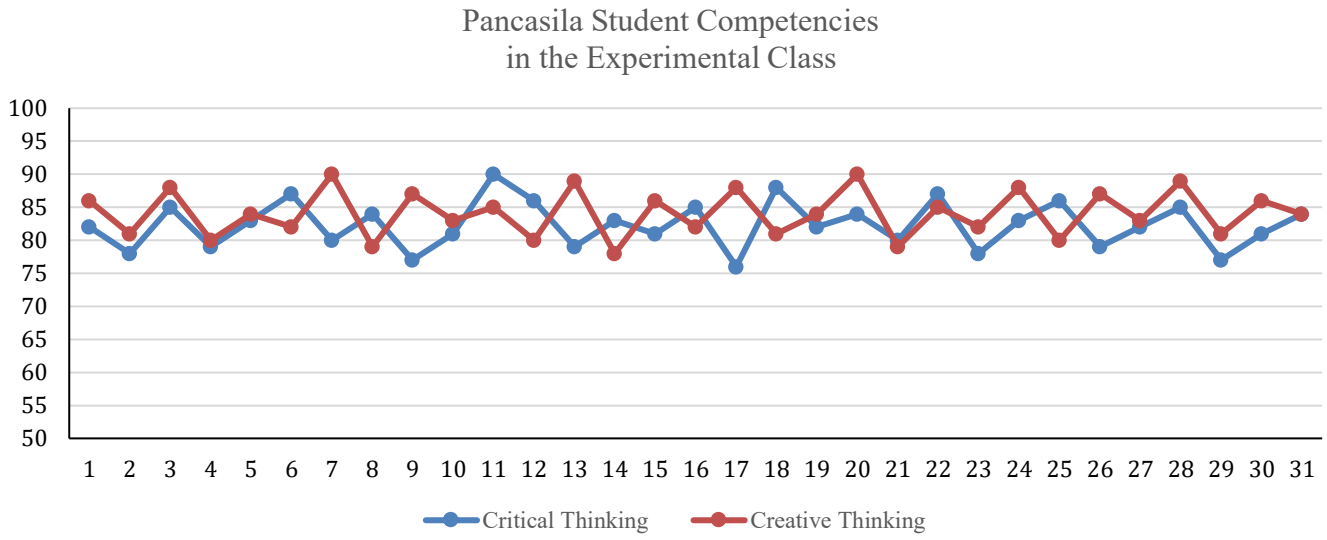

Figure 1. Pancasila Student Competencies in the Experimental Class

Based on the data in Figure 2, Pancasila Student competencies in the control class, as reflected in critical thinking and creative thinking, show a moderate level of achievement with relatively small variation. Students' critical thinking scores range from 62 to 75, with the lowest score being 62 and the highest 75. Meanwhile, creative thinking scores range from 65 to 76, with the lowest score being 65 and the highest 76. In general, creative thinking scores tend to be slightly higher than critical thinking scores, although the difference is not significant. This indicates that without the implementation of project-based learning, Pancasila Student competencies, particularly in critical and creative thinking, develop at an adequate but not optimal level.

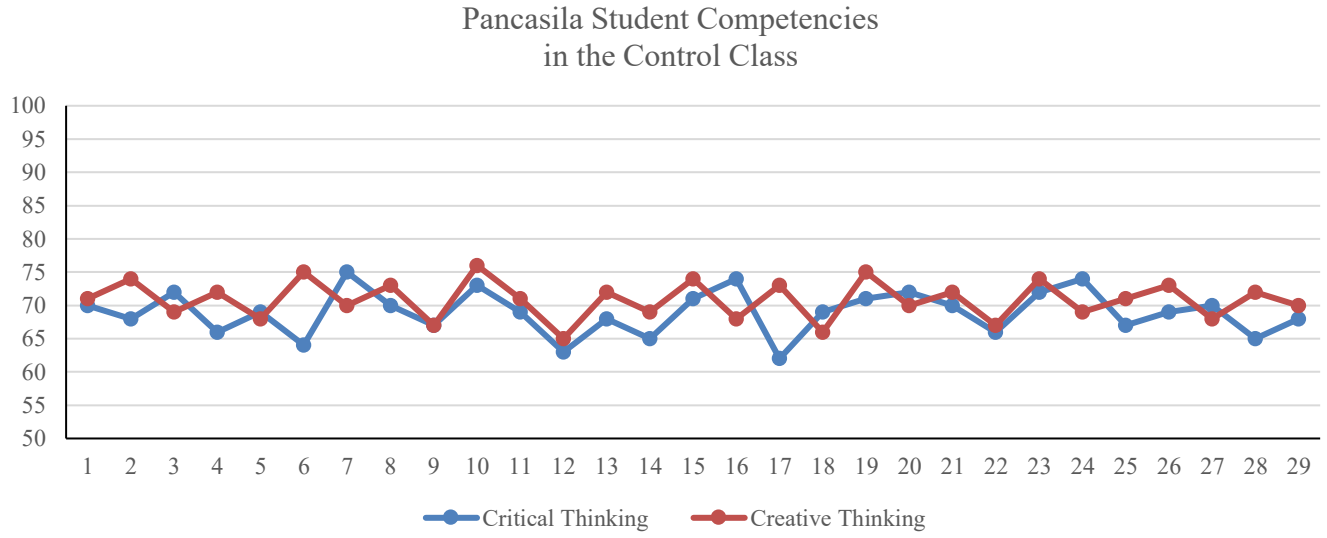

Figure 2. Pancasila Student Competencies in the Control Class

The results of descriptive statistical analysis in Table 6 show that students' critical thinking ability in the experimental class has a mean score of 82.32 with a standard deviation of 3.54, while the control class has a mean of 68.93 with a standard deviation of 3.34. This indicates that the critical thinking ability of students in the experimental class is higher than that of the control class. In addition, the relatively small standard deviation in both classes suggests that the data distribution is fairly homogeneous and not widely spread. For creative thinking ability, the experimental class has a mean score of 84.10 with a standard deviation of 3.54, while the control class has a mean of 70.83 with a standard deviation of 2.89. These results indicate that students' creative thinking ability in the experimental class is also higher than that of the control class. The relatively small standard deviation further shows that the variation of data in both classes is not large.

Table 6. Descriptive Statistics

Pancasila Student Competencies	Class	Mean	Std. Deviation	N
Critical Thinking	Experimental Class	82.3226	3.54389	31
	Control Class	68.9310	3.33735	29
	Total	75.8500	7.56402	60
Creative Thinking	Experimental Class	84.0968	3.54358	31

Control Class	70.8276	2.89172	29
Total	77.6833	7.42075	60

Overall, both critical thinking and creative thinking abilities show higher mean scores in the experimental class compared to the control class. This indicates that the implementation of project-based learning through a mini hydropower project tends to improve Pancasila Student competencies, particularly in the aspects of students' critical and creative thinking.

The results of the linearity test indicate that there is a fairly strong linear relationship between creative thinking and critical thinking as dependent variables in the MANOVA analysis. This is shown by the correlation coefficient (R) value of 0.796, which indicates a strong relationship, and the R Square value of 0.634, meaning that approximately 63.4% of the variation in critical thinking ability can be explained by creative thinking ability. In addition, the Adjusted R Square value of 0.628 indicates that the model remains stable after being adjusted for the sample size. Thus, it can be concluded that the relationship between the two dependent variables is linear and meets one of the assumptions required for MANOVA analysis.

The results of the normality test show that the data for critical thinking and creative thinking in both classes are normally distributed. This is indicated by the significance values in the Shapiro-Wilk test for all groups being greater than 0.05, namely 0.846 for critical thinking in the experimental class and 0.873 in the control class, as well as 0.218 for creative thinking in the experimental class and 0.723 in the control class. In addition, the Kolmogorov-Smirnov test also shows a significance value of 0.200 for all groups, indicating that the data do not significantly differ from a normal distribution. Therefore, it can be concluded that all research data meet the normality assumption required for MANOVA analysis.

The results of the homogeneity of covariance matrices test using Box's Test indicate that the data meet the homogeneity assumption as one of the requirements for MANOVA analysis. This is shown by the significance value of 0.611, which is greater than 0.05, indicating that there is no significant difference in covariance matrices between groups. Thus, the null hypothesis stating that the covariance matrices of the dependent variables are equal across the experimental and control classes is accepted. Therefore, it can be concluded that the data meet the homogeneity of covariance matrices assumption and are suitable for further MANOVA analysis. The results of the multivariate test are presented in Table 7.

Table 7. Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.999	32218.589[b]	2.000	57.000	.000	.999
	Wilks' Lambda	.001	32218.589[b]	2.000	57.000	.000	.999
	Hotelling's Trace	1130.477	32218.589[b]	2.000	57.000	.000	.999
	Roy's Largest Root	1130.477	32218.589[b]	2.000	57.000	.000	.999
Class	Pillai's Trace	.895	243.795[b]	2.000	57.000	.000	.895
	Wilks' Lambda	.105	243.795[b]	2.000	57.000	.000	.895
	Hotelling's Trace	8.554	243.795[b]	2.000	57.000	.000	.895
	Roy's Largest Root	8.554	243.795[b]	2.000	57.000	.000	.895

a. Design: Intercept + Class
b. Exact statistic

The results of the multivariate test in Table 7 indicate that there is a significant effect of the class variable on Pancasila Student competencies, which include critical thinking and creative thinking. This is evidenced by the significance values of all multivariate statistics, including Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root, all of which are 0.000 ($p < 0.05$). The Wilks' Lambda value of 0.105 indicates a strong difference between the experimental and control classes. In addition, the F value of 243.795 with degrees of freedom (2, 57) indicates that the difference is highly statistically significant. The Partial Eta Squared value of 0.895 indicates that the effect of the learning model on the two dependent variables is very large, meaning that approximately 89.5% of the variation in critical thinking and creative thinking is influenced by the difference in treatment between the classes. Thus, it can be concluded that there is a significant difference between the experimental and control classes simultaneously in terms of Pancasila Student competencies.

Discussion

The results of the study indicate that the implementation of the Project-Based Learning (PjBL) model through a mini hydropower model project has a significant effect on improving students' critical thinking and creativity competencies. This is evident from the higher mean scores of both competencies in the experimental class compared to the control class. In addition, the results of the one-way MANOVA analysis also show that the implementation of the PjBL model has a significant effect on both dependent variables simultaneously. These findings suggest that project-based learning provides more meaningful learning experiences compared to conventional instruction [22].

The improvement in students' critical thinking ability in the experimental class can be explained by the characteristics of the Project-Based Learning model, which emphasizes systematic problem-solving processes. In project-based learning, students are not only passive recipients of information but are actively involved in identifying problems, analyzing concepts, designing solutions, and evaluating the outcomes of their projects [23]. This process encourages students to utilize higher-order thinking skills in understanding renewable energy concepts and the working principles of hydropower systems. As a result, students are able to develop deeper analytical, evaluative, and inferential skills [24].

In addition to improving critical thinking, the implementation of Project-Based Learning has also been shown to enhance students' creativity. The activity of designing and constructing a mini hydropower model provides opportunities for students to generate new ideas in designing the device, selecting appropriate materials, and developing turbine mechanisms to generate electrical energy. This process encourages flexible and innovative thinking in solving problems encountered during project development. Therefore, project-based learning can serve as an effective approach to fostering students' creativity [25].

These findings are consistent with previous studies indicating that Project-Based Learning can improve higher-order thinking skills and creativity in science education. This model offers authentic learning experiences as students are directly involved in investigation and product creation activities. Through these experiences, students not only understand concepts theoretically but also apply their knowledge in real-life contexts. Therefore, PjBL is considered a relevant learning model for developing 21st-century competencies [26].

In the context of education in Indonesia, the development of critical thinking and creativity is an essential component of implementing the Pancasila Student Profile. The critical thinking dimension emphasizes students' ability to obtain and process information objectively, analyze problems, and make rational decisions. Meanwhile, the creativity dimension emphasizes the ability to generate innovative and meaningful ideas or products. Through the implementation of Project-Based Learning in the mini hydropower project, these two dimensions can be developed simultaneously through active and contextual learning processes [27].

The project activities conducted in this study provide opportunities for students to work collaboratively in designing and constructing the mini hydropower model. During this process, students learn to plan the steps of construction, identify challenges, and find solutions to overcome difficulties encountered. This process not only enhances critical thinking but also promotes creativity in designing effective and efficient models [28].

In addition to contributing to the development of the Pancasila Student Profile, renewable energy learning through the mini hydropower project is also relevant to the global agenda of the Sustainable Development Goals (SDGs). One of the SDGs related to education is SDG 4: Quality Education, which emphasizes the importance of education that fosters critical thinking, creativity, and problem-solving skills [29]. By implementing project-based learning, the learning process becomes more active, contextual, and oriented toward the comprehensive development of students' competencies [30].

Furthermore, learning about renewable energy also supports the achievement of SDG 7: Affordable and Clean Energy, which aims to ensure access to clean, affordable, and sustainable energy. Through activities such as designing a mini hydropower model, students not only understand renewable energy concepts theoretically but also gain hands-on experience in utilizing environmentally friendly energy sources. This can enhance students' awareness of the importance of renewable energy in supporting sustainable development [31].

The integration of project-based learning, the strengthening of the Pancasila Student Profile, and sustainable development issues demonstrates that science education can be designed contextually to address global challenges. By linking renewable energy topics with real-world projects, students can understand the connection between scientific concepts and real-life problems. This makes the learning process more relevant and meaningful [32]. Therefore, the findings of this study indicate that the implementation of Project-Based Learning through a mini hydropower project is not only effective in improving students' critical thinking and creativity but also supports the implementation of the Pancasila Student Profile and contributes to achieving the Sustainable Development Goals, particularly in the areas of quality education and sustainable clean energy [33].

4. Conclusion

Based on the results of the study and discussion, it can be concluded that the implementation of Project-Based Learning through a mini hydropower model project in science learning is able to strengthen Pancasila Student competencies, particularly in the dimensions of critical thinking and creativity. Project-based learning provides opportunities for students to actively engage in identifying energy-related problems, designing solutions, and producing outputs related to the use of renewable energy. Through this process, students not only understand energy concepts theoretically but are also able to develop analytical thinking skills and generate creative ideas in designing mini hydropower models. Therefore, project-based learning on renewable energy topics can serve as an effective instructional strategy to support the strengthening of Pancasila Student competencies while also improving the quality of science learning to be more contextual and meaningful.

The results of this study imply that science learning designed through a project-based approach can be an effective alternative strategy for developing students' 21st-century competencies. Teachers can utilize project activities related to real-world issues, such as renewable energy utilization, to encourage students to think critically and creatively during the learning process. Furthermore, integrating mini hydropower projects into science learning can help students understand the connection between scientific concepts and sustainable development issues, making learning more relevant to everyday life. This approach also supports the implementation of the Merdeka Curriculum through the strengthening of the Pancasila Student Profile and contributes to the achievement of the Sustainable Development Goals, particularly in the areas of quality education and sustainable clean energy.

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