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The Effect of Project-Based Learning in Building Water Rockets on Elementary School Students' Independent Learning and Critical Thinking

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Abstract

The development of 21st-century skills, particularly learning independence and critical thinking, has become an important focus in elementary education. However, many elementary school students still demonstrate limited independence in managing their learning processes and underdeveloped critical thinking skills due to the dominance of conventional teacher-centered learning approaches. Project-Based Learning (PjBL) is considered an effective instructional model because it encourages students to actively construct knowledge through meaningful experiences, problem-solving activities, and real-world projects. This study aimed to examine the effect of water rocket-based Project-Based Learning on elementary school students' learning independence and critical thinking skills. The research employed a quantitative quasi-experimental method using a Nonequivalent Control Group Design. The participants were elementary school students from the Rantasari Cluster, Ajibarang District, with data collected through observation, critical thinking tests, and documentation. Data analysis was conducted using prerequisite tests, independent-samples t-tests, and Pearson correlation analysis. The results showed that PjBL through water rocket-making activities significantly improved students' critical thinking skills ($p = 0.023 < 0.05$) and learning independence ($p = 0.012 < 0.05$) compared with conventional learning methods. Furthermore, critical thinking skills and learning independence demonstrated a significant moderate relationship, with a correlation coefficient of 0.490. These findings indicated that water rocket-based PjBL provided meaningful learning experiences that promoted student autonomy, exploration, collaboration, and higher-order thinking skills. Therefore, PjBL can be recommended as an innovative instructional strategy to strengthen elementary students' critical thinking and independent learning abilities.

INTRODUCTION

Education serves as a fundamental pillar in the development of civilization and plays a strategic role in improving the quality of a nation's human resources. Through education, Indonesia seeks to develop a generation that excels not only in intellectual abilities but also possesses strong character, mastery of 21st-century skills, and global competitiveness. Considering the complexity of challenges arising from the Industrial Revolution 4.0 and digital transformation, the national curriculum must remain adaptive to contemporary social, economic, and technological developments (Diachuk, 2024; Lubis et al., 2022). In response to the need to achieve the primary objectives of the national education system, which include improving citizens' quality of life and developing individual potential as mandated in the fourth paragraph of the Preamble to the 1945 Constitution, the government introduced the Merdeka Curriculum as an innovation designed to overcome the limitations of previous curriculum models. The Merdeka Curriculum provides greater flexibility for teachers and educational institutions to manage learning processes by emphasizing differentiated instruction, the implementation of Project-Based Learning (PjBL), and authentic assessment to support student character development (Syafriani et al., 2025).

The Merdeka Curriculum was introduced in 2022 as part of the government's efforts to strengthen educational autonomy at the school level. The transition from the 2013 Curriculum to the Merdeka Curriculum represents another stage in the history of curriculum development in Indonesia. Prior to its implementation, Indonesia had experienced eleven curriculum changes recorded from 1947 to the end of 2022 (Amalia & Asyari, 2024). The implementation of the Merdeka Curriculum in early 2022 emphasized project-based learning and the strengthening of the Profil Pelajar Pancasila (Pancasila Student Profile) (Firmansyah, 2023).

At the beginning of the 2025/2026 academic year, Indonesian education introduced the concept of deep learning and the eight dimensions of the graduate profile based on Permendikdasmen Number 13 of 2025. Deep learning and the eight dimensions of the graduate profile replaced the previous dimensions of the Pancasila Student Profile that were implemented when the Merdeka Curriculum was initially developed. In the 2013 Curriculum, assessment domains included knowledge, attitudes, and skills. Across various curriculum frameworks, two important graduate characteristics have remained consistent: the development of students' learning independence and critical thinking skills.

Learning independence and critical thinking skills are essential aspects that should be continuously developed through educational activities (Irwan & Aslan, 2024; Kusmaryono, 2023; Romadhon & Aslan, 2025). Learning independence is an important factor influencing student achievement because success in learning depends not only on teacher guidance and structured assignments but also on students' ability to regulate and manage their own learning processes (Ilmaknun & Ulfah, 2023). Education can be understood as a process of guidance provided by educators to help students achieve maturity and develop the ability to manage their lives independently (Purnomo, 2019; Hidayat & Abdillah, 2019).

Learning independence among elementary school students is a character trait that develops through continuous habituation rather than hereditary inheritance (Hasyim et al., 2024; Wardat, 2024). This development is strongly influenced by environmental factors, including family and school contexts (Septiadevana et al., 2024). Therefore, students' learning independence requires continuous support and stimulation to strengthen autonomous learning behaviors. Through the development of independent learning characteristics, students are expected to improve learning quality, enhance problem-solving abilities, increase motivation, and achieve better learning outcomes (Järvenoja et al., 2023).

However, several studies have shown that the level of learning independence among elementary school students in Indonesia remains relatively low (Rovita et al.; Firdaus et al., 2024). Students tend to rely heavily on teacher instructions, demonstrate limited learning initiative, and experience difficulties in managing time and evaluating their own learning outcomes independently (Qorimah & Laksono, 2023). This condition is partly influenced by learning practices that remain oriented toward conventional approaches, where teachers frequently dominate classroom activities through lectures and memorization-based assignments (Arrahman et al., 2024).

Critical thinking skills represent another essential competency that students must develop alongside learning independence (Aston, 2024; Salsa et al., 2023). Critical thinking enables students to receive, analyze, and process information logically, allowing them to solve problems and make appropriate decisions (Lestari et al., 2024; Volkotrubova et al., 2024). These skills should be developed from the elementary school level because they support students in analyzing information, evaluating evidence, and constructing logical arguments. However, results from the Programme for International Student Assessment (PISA) indicate that Indonesian students' literacy, numeracy, and science performance remain below the international average. This condition suggests that students' critical thinking abilities require further improvement, as classroom practices often remain focused on memorization rather than conceptual understanding and problem-solving.

One strategy that can be implemented to improve learning independence and critical thinking skills is Project-Based Learning (PjBL). This instructional model positions students as active participants by engaging them in meaningful projects connected to real-world contexts. Based on constructivist learning theory, PjBL encourages students to construct knowledge through direct experiences, inquiry activities, collaboration, and problem-solving processes. Previous studies have demonstrated that PjBL can improve conceptual understanding, learning motivation, critical thinking skills, collaboration abilities, and student learning independence. Therefore, this model aligns with the objectives of the Merdeka Curriculum, which emphasizes contextual, active, and student-centered learning (Hwang & Chen, 2020).

One relevant project that can be implemented in elementary school IPAS (Ilmu Pengetahuan Alam dan Sosial; Science and Social Studies) learning is water rocket construction. This project integrates science, mathematics, and technology concepts through the design, construction, and testing of water rockets based on the principles of thrust and action–reaction forces. In addition to being engaging and enjoyable, water rocket construction uses materials that are easily accessible, safe, and appropriate for elementary school students. Through direct involvement in the project process, students are expected to develop learning independence and critical thinking skills more effectively. Based on this background, this study was conducted to examine the effect of water rocket-based Project-Based Learning on elementary school students' learning independence and critical thinking skills.

METHOD

This study employed a quantitative quasi-experimental approach using a Nonequivalent Control Group Design (Muin, 2023). The experimental group received treatment through the implementation of the Project-Based Learning (PjBL) model assisted by water rocket projects, while the control group received conventional learning methods. Both groups were administered pretests before the intervention and posttests after the intervention to evaluate differences in learning outcomes resulting from the treatment.

Place and Time of Research

This research was carried out in seven State Elementary Schools that are members of the Rantasari Cluster, Ajibarang District, namely SD Negeri 1 Banjarsari, SD Negeri Kalibenda, SD Negeri 1 Sawangan, SD Negeri 2 Sawangan, SD Negeri 1 Jingkang, SD Negeri 2 Jingkang, and SD Negeri 3 Jingkang. The selection of this location is based on the consideration that the application of the PjBL model, especially those assisted by water rockets, is still very limited in these schools, so this research is expected to make a real contribution to improving the quality of learning. The implementation of the research lasted for three months, from October to December 2025, which included the preparation and validation stage of the instrument in October, data collection from November to December, and data analysis in December.

Research Variables

This study involved three main variables. The free variable (X) is a water rocket-assisted Project-Based Learning (PjBL) learning model, which is a project-based learning model that invites students to actively design, manufacture, and launch water rockets as a form of application of natural and social science (IPAS) concepts (Arib et al., 2024). The first bound variable (Y1) is student learning independence, which reflects the student's ability to manage and manage their learning process independently. The second bound variable (Y2) is the student's critical thinking ability, which is the student's ability to analyze, evaluate, and draw logical conclusions from the information obtained during learning.

Population and Sample

The population in this study is all State Elementary School students in the Rantasari Cluster, Ajibarang District consisting of seven public elementary schools. Sampling was carried out using the cluster random sampling technique, which is a random selection of samples based on the existing school group or cluster, so that each school has the same opportunity to be selected as a research sample.

Data Collection Techniques and Instruments

The data in this study was collected through three techniques. First, observations are carried out to observe and record students' learning independence directly during the activity process, from the creation to the launch of water rockets. Observations are carried out using observation sheets that have been validated by experts to ensure that the instrument really measures the aspect in question. Second, the test is used to measure students' critical thinking skills through pretest questions given before treatment and posttest questions given after treatment. The comparison between the results of the two is the basis for seeing changes in students' critical thinking skills. Third, documentation is used to obtain supporting data related to school conditions and research processes, so that it can strengthen the findings obtained in the field.

Data Analysis Techniques

Data analysis is carried out through two main stages. The first stage is the prerequisite test, which consists of a normality test and a homogeneity test. The normality test was carried out using the Kolmogorov-Smirnov method with the help of SPSS version 25 to find out whether the distributed data is normal or not, with the criteria of data being declared normal if the significance value is ≥ 0.05. The homogeneity test was carried out to determine whether the data variance between groups was homogeneous, with the same criterion, namely a significance value of ≥ 0.05.

The second stage is the hypothesis test, which is carried out based on the results of the prerequisite test. If the data is distributed normally, the hypothesis test uses the Independent Sample T-test parametric test, but if the data is not normally distributed, the Mann Whitney non-parametric test is used. The research hypothesis is accepted if there is a significant difference in the mean value between the experimental group and the control group, with the significance level used being 0.05.

RESULTS AND DISCUSSION

Data Analysis Results

In this section, the results of the analysis of research data obtained from the implementation of activities in the control class and the experimental class are presented. Data analysis was carried out to determine the influence of the treatment given and to answer the formulation of the problem that had been determined in the research (López-Martínez & Pérez-Martín, 2025). The data analyzed included *pretest* and *posttest* results as well as observation data related to research variables.

The analysis process is carried out through several stages, including prerequisite tests, namely normality tests and homogeneity tests, hypothesis tests according to the type of data and research design used. All data analysis was carried out using SPSS version 25 *for Windows* so that the results obtained were more accurate and scientifically accountable.

The results of data analysis presented in this sub-chapter include the results of prerequisites and statistical tests used to test research hypotheses. The presentation of the results is carried out systematically in order to provide a clear picture of the research findings, so as to support the discussion process in the following subchapters.

1. Variables of Critical Thinking Control and Experiment Classes

a. Normality Test of Critical Thinking Control and Experiment Class

The basis for decision-making in the normality test is based on the significance value (Sig.) that has been obtained from the results of statistical testing. If the significance value (Sig.) is greater than 0.05, it can be declared to be normally distributed. However, on the other hand, if the significance value (Sig.) is less than 0.05, it can be declared not normally distributed. The use of these criteria aims to determine whether or not the assumption of normality is fulfilled as one of the prerequisites contained in parametric statistical analysis.

Table 1. Normality Test of Critical Thinking Control and Experimental Classes

	Kolmogorov-Smirnova			**Shapiro-Wilk**		
	Statistic	df	Sig.	Statistic	df	Sig.
Critical Thinking Control	.108	30	.200*	.967	30	.465
Experimental Critical Thinking	.140	30	.139	.936	30	.073

In the normality test table above there are two columns, namely, Kolmogorov-Smirnov and Shapiro-Wilk. The use of Kolmogorov-Smirnov and Shapiro Wilk was determined by the number of respondents. If the number of respondents is more than 50 respondents, then use Kolmogorov-Smirnov, but if the number of respondents is less than 50, use Shapiro-Wilk. Because the number of respondents in this study was 30 respondents, the results of the significance value (Sig.) from Shapiro-Wilk were used.

In accordance with the results of the normality test in the table above, the results of the normality test are declared normal, because the normality test requirement must be greater than 0.05. Based on the table of results of the significance value (Sig.) of the control class 0.465 is greater than 0.05, meaning that the data is distributed normally. While the results of the significance value (Sig.) of the experimental class, which is 0.073 greater than 0.05, the data is declared to be distributed normally. From the two data from the normality test results in the control class and the experimental class, it can be concluded that the results of the significance value (Sig.) are both declared to be normally distributed because the test results of both are more than 0.05. This shows that both data meet the normal distribution requirements, so that data analysis can be continued using parametric statistical methods.

b. Homogeneity Test of Critical Thinking Control and Experiment Classes

Homogeneity test is a test that is carried out to find out that two or more sample data groups come from a population that has the same variance (homogeneous). This test is a prerequisite before performing other tests, such as *the T-test* and ANOVA (variance analysis). This test is used to ensure that the data group does indeed come from a population that has the same variance (homogeneous).

Through the homogeneity test, the researcher can ensure that the analyzed differences are not affected by the variance between groups, so that the test results become more valid. The decision-making criteria in the homogeneity test are based on the significance value (Sig.), that is, if the significance value (Sig.) is greater than 0.05, the data is declared homogeneous, while if the significance value is less than 0.05, the data is declared inhomogeneous. Homogeneity tests can be performed using several statistical methods, including the Levene test, the Fisher test, or the Bartlett test, the selection of which is adjusted to the characteristics and assumptions of the data used.

Table 2. Homogeneity Test of Critical Thinking Control and Experiment

Critical Thinking Control Experiments

Levene Statistic	df1	df2	Say.
.065	1	59	.799

ANOVA

Critical Thinking Control Experiments

	Sum of Squares	df	Mean Square	F	Say.
Between Groups	6312.670	1	6312.670	63.487	.000
Within Groups	5866.477	59	99.432		
Total	12179.148	60			

Based on the homogeneity test in the table above using the Levenne test, the results of the significance value (Sig.) collaboration between the control class and the experiment showed a significance value (Sig.) of 0.799 which showed a significance value (Sig.) of more than 0.05 which means that it was in accordance with the rules in the homogeneity test. From these results, it can be concluded that the two sample data groups contained in the control class and the experimental class came from a population that had the same variance (homogeneous). Thus, the data has met one of the homogeneity test prerequisites so that the data analysis can be continued to the parametric analysis stage using the *Independet Sample T-Test comparison test*.

c. Independent Sample T-Test Critical Thinking

The independent sample T-test aims to compare the averages of two unrelated groups (*independent*) to determine whether the two groups have significant statistical differences.

More specifically, the independent sample t-test is used to test the hypothesis of whether two populations each represented by a sample have the same or different average values.

In order to produce an appropriate analysis, the independent sample t-test requires the fulfillment of several basic assumptions that are interconnected. First, the data used on each group must be distributed normally, which means that the distribution of the scores accumulates at the average value and does not deviate far in contrast. Second, the subjects in the study must be sourced from two independent groups, where members of one group are not related or unaffected to the other group members (comparing the control class and the experimental class). Finally, although this test can be performed on a small sample, the most stable and accurate results are obtained if the two groups have an equal (balanced) and large enough sample number, as the availability of a sufficient number of samples can help increase the statistical power in identifying the real differences in each group.

The basis for decision-making in the independent sample t-test focuses on the comparison between the significance value (*Sig. 2-tailed*) and the alpha criterion of 0.05. If the significance value (Sig.) is less than 0.05, then the null hypothesis (H0) is rejected, which means that there is a statistically significant mean difference between the two groups. On the other hand, if the significance value (Sig.) is more than 0.05, then the hypothesis of zero (H0) is accepted, indicating that there is no significant difference between the two groups and that the differences that arise occur due to the influence of the treatment given.

2. Variables of Independence of Control and Experimental Classes

a. Control and Experimental Class Independence Normality Test

The basis for decision-making in the normality test is based on the significance value (Sig.) that has been obtained from the results of statistical testing. If the significance value (Sig.) is greater than 0.05, it can be declared to be normally distributed. However, on the other hand, if the significance value (Sig.) is less than 0.05, it can be declared not normally distributed. The use of these criteria aims to determine whether or not the assumption of normality is fulfilled as one of the prerequisites contained in parametric statistical analysis.

Table 3. Normality Test of Learning Independence in Control and Experimental Classes

	Kolmogorov-Smirnova			**Shapiro-Wilk**		
	Statistic	df	Say.	Statistic	df	Say.
Control Class	.134	31	.166	.936	31	.064
Experimental Classes	.193	31	.005	.908	31	.011
Lilliefors Significance Correction						

In the table above there are two columns, namely Kolmogorov-Smirnov and Shapiro-Wilk, The use of Kolmogorov-Smirnov and Shapiro Wilk is determined by the number of respondents. If the number of respondents is more than 50 respondents, then use Kolmogorov-Smirnov, but if the number of respondents is less than 50, use Shapiro-Wilk. Because the number of respondents in this study was 31 respondents, the results of the sig from Shapiro-Wilk were used.

The results of the Normality Test are declared normal, because the normality test requirement must be greater than 0.05. Based on the table of sig values. The control class refers to the value of the GIS. 0.064 which is greater than 0.05, meaning that the data is normally distributed. While the value of sig. The experimental class is 0.011 which is smaller than 0.05, then the data is declared not normally distributed. From the two data, the results show that the data in the control class is normally distributed, while the data in the experimental class is not distributed normally. Because the assumption of normality of the two data is not the same and there is one of the abnormal data, the data is included in the Non-Parametric category,

b. Control Class and Experimental Class Independence Homogeneity Test

Homogeneity test is a test that is carried out to find out that two or more sample data groups come from a population that has the same variance (homogeneous). This test is a prerequisite before conducting other tests, such as the T-test and anova. This test is used to ensure that the data group does indeed come from a population that has the same variance (homogeneous).

Through the homogeneity test, the researcher can ensure that the analyzed differences are not affected by the variance between groups, so that the test results become more valid. The decision-making criteria in the homogeneity test are based on the significance value (Sig.), that is, if the significance value (Sig.) is greater than 0.05, the data is declared homogeneous, while if the significance value is less than 0.05, the data is declared inhomogeneous. The homogeneity test can be carried out using several statistical methods, including the Levene Test, the Fisher Test, or the Bartlett Test, which are selected according to the characteristics and assumptions of the data used.

Table 4. Test of Homogeneity of Learning Independence in Control and Experiment Classes

Experimental Control Class			
Levene Statistic	df1	df2	Say.
.000	1	60	.985

ANOVA					
Experimental Control Class					
	Sum of Squares	df	Mean Square	F	Say.
Between Groups	9.290	1	9.290	3.823	.055
Within Groups	145.806	60	2.430		
Total	155.097	61			

According to the homogeneity test using the Levenne test, the results of the independence of the control and experimental classes showed a significance value greater than 0.05, which was 0.985. In accordance with the decision-making rules in the homogeneity test, if the sig value is more than 0.05, the variance of the data in the experimental class and the control class is said to be homogeneous.

It can be concluded that, between the experimental class and the control class, there is an equal or similar diversity of data, so it is eligible for further parametric statistical testing, namely the *independent sample t-test,* because the prerequisites have been met.

c. Independent Sample T-test Learning Independence

The independent sample T-test aims to compare the averages of two unrelated groups (independent) to determine whether the two groups have prominent statistical differences.

More specifically, the independent sample T-test is used to test the hypothesis of whether two populations are each represented by a sample that has the same or different mean values.

In order to produce a suitable analysis, the Independent Sample T-test requires the fulfillment of several basic assumptions that are interrelated. First, the data in each group must be distributed normally, which means that the distribution of the score accumulates at the average value and does not skew extremely. Second, the subjects in the study must come from two independent groups, where members of one group have no connection or influence on the other group members (comparing the control class and the experimental class). Finally, although this test can still be performed on small samples, the most stable and accurate results are obtained if both groups have the same (balanced) and large enough sample counts, as the availability of an adequate number of samples can help increase the statistical power of detecting real differences in each group.

The basis for decision-making in the Independent Samples T-Test focuses on the comparison between the significance value (Sig. 2-tailed) and the alpha criterion of 0.05. If the significance value (Sig.) is less than 0.05, then the null hypothesis (H_0) is rejected, which means that there is a statistically significant average difference between the two groups, and indicates that the treatment given has a real effect. Conversely, if the significance value (Sig.) is more than 0.05, then the null hypothesis (H_0) is accepted, indicating that there is no significant difference between the two groups and that the small differences that arise occur only due to chance factors, not due to the influence of the treatment given. The results of the independent sample t-test critical thinking in both classes can be seen in the following table

Table 5. Results of the Independent Sample T-Test of Learning Independence in Control and Experiment Classrooms

	Classes	N	Mean	Std. Deviation	Std. Error Mean
Experimental	1	31	9.19	1.621	.291
Control Class	2	31	9.97	1.494	.268

The results of the data analysis showed that the significance value (Sig.) produced was 0.012. Given that the figure is smaller than the threshold of 0.05 ($0.012 < 0.05$), it is concluded that the hypothesis in this study is accepted (and H_0 is rejected). This led to the conclusion that there was a significant difference in the average results of student independence in the control class and the experimental class, which indicates that the treatment given to the experimental group had a significant impact on improving student independence when compared to the control group.

3. Pearson Correlation Test (*Pearson Product Moment*) to determine the strength and direction of the relationship between Critical Thinking and Experimental Class Independence

The Pearson product moment *test* is a parametric statistical method used to measure the strength and direction of the linear relationship between two variables. In order for the results of this analysis to be valid and accurate, the research must meet several main prerequisites, namely the data must have an interval or ratio measurement scale and must be distributed normally. In addition, the relationship between the two variables must be linear, and it must be ensured that there are no extreme outlier values that can interfere with the results of the correlation coefficient calculation.

The basis of decision-making in the correlation test is determined through the significance value (Sig.). If the value of Sig. < 0.05, then it can be concluded that the two variables have a significant (correlated) relationship. On the other hand, if the Sig. value > 0.05, then the relationship is considered insignificant or uncorrelated. Once the significance status is known, the strength of the relationship between variables can be assessed through *Pearson Correlation numbers*.

The strength of the relationship between variables in this analysis is determined based on the value of *the Pearson Correlation* coefficient which is divided into five main categories. A coefficient value between 0.00 to 0.20 indicates that there is almost no correlation between variables, while a value of 0.21 to 0.40 indicates a correlation with weak strength. If the coefficient is in the range of 0.41 to 0.60, the relationship is categorized as a moderate correlation. The strength of the relationship will be considered strong if the coefficient value reaches the range of 0.61 to 0.80, and the peak, the value of 0.81 to 1.00 indicates a very strong relationship to a perfect correlation.

Table 6. Pearson Correlation Test (*Pearson Product Moment*) to determine the strength and direction of the relationship between Critical Thinking and Experimental Class Independence

		Experimental Critical Thinking	Experimental Independence
Experimental Critical Thinking	Pearson Correlation	1	.490**
	Sig. (2-tailed)		.006
	N	30	30
Experimental Independence	Pearson Correlation	.490**	1
	Sig. (2-tailed)	.006	
	N	30	31

*****. Correlation is significant at the 0.01 level (2-tailed).***

SPSS Results: Based on the results of the statistical test output in the table above, it is known that the significance value or Sig. (2-tailed) obtained is 0.006. Since the value is smaller than the threshold of 0.05, it can be concluded that these variables are correlated, which means that there is a significant relationship between the critical thinking variable and the level of student independence. However, if reviewed from the results of the SPSS calculation, it was found that the correlation coefficient was 0.490. This coefficient number shows that the strength of the relationship between critical thinking and independence is actually in the category of a moderate correlation relationship.

The Effect of Project-Based Learning on the Learning Independence and Critical Thinking of Elementary School Students. The project-based learning model (PjBL) of making water rockets can help increase students' sense of learning independence and critical thinking skills.

In an effort to measure the effectiveness of the intervention strongly, the research design began by collecting data related to the initial ability of students in both samples, namely in the experimental class and the control class through the provision of pretests. This initial study is very fundamental and crucial to be able to ensure that the research subjects have the same basic competencies before being given different actors through the project-based learning model (PjBL) of water rocket making. Then, in line with Cresswell's opinion (in Chrisdiyanto and Hamdi, 2023) regarding the principle of learning outcome evaluation which explains that the posttest applied at the end of the experimental activity aims to map the results of the final learning outcomes and to measure the extent to which the shift in student performance occurs after being exposed to each approach or treatment in the learning activity.

The results of the initial data analysis through a pretest related to critical thinking skills and learning independence proved that both groups between the experimental group and the control group had equal starting points. The validity of the similarity is strengthened by the results of the assumption test which shows that the sample data results from the two groups are normally distributed and have a homogeneous variance. After being given treatment to each group, there was an escalation in the average score on the indicators of critical thinking ability and learning independence in both classes. However, the experimental group recorded a more significant score than the control class, thus creating a differentiation in real achievement between the two groups. These findings are in line with the results of research conducted by Ati and Setiawan (2020) which is also supported by research from Chrisdiyanto and Hamdi (2023) published in the Journal of Mathematics Education Research, which emphasizes that the use of the project-based learning model (PjBL) approach can have an effective impact in improving students' critical thinking skills. The project-based learning model (PjBL) can help improve students' learning abilities, this is in accordance with the results of research conducted by Nurhamidah & Nurachadijat (2023) which explains that the project-based learning model (PjBL) has proven to be effective in helping to increase student learning independence because it applies a contextual approach through problem-solving investigation activities and meaningful activities.

The results of the study show that the project-based learning model (PjBL) of making water rockets has a significant effect on increasing students' learning independence and critical thinking. The experimental group that conducted the hands-on practice independently scored higher on the test compared to the control group that followed conventional learning without the practice of making water rockets independently. Because the practice of making water rockets can provide opportunities and space for students to be able to explore extensively related to independent decision-making in each stage of the project step so that it can strengthen students' understanding of the material being taught.

Through this water rocket project-based learning model, students are not only passive subjects, but also play an active role as the main actors who take full responsibility from planning, designing, assembling, to testing the products they produce themselves (water rockets). Independence in learning is created when students try to overcome various technical problems that they encounter in the process independently without having to rely entirely on intuition or direction from the teacher. This shows that the characteristics of project-based learning (PjBL) of water rocket making that focus on solving concrete problems indirectly force students to organize, manage, and find solutions during the process independently. In the project-based learning model (PjBL) of water rocket linkage, students experience a trial and error learning cycle that can help build confidence and initiative in students naturally which will have an effect on the formation of consistent patterns of student learning independence.

The project-based learning model (PjBL) of water rocket making also has an impact on students' critical thinking skills, which spontaneously when students analyze things that are the cause of success or failure when conducting launch trials of water rocket products that students have created. This real-world experience can then strengthen students' understanding and knowledge of what they are learning, while also helping to increase their learning independence and critical thinking skills.

In an effort to increase students' learning independence and critical thinking skills towards cognitive aspects, the selection and use of the project-based learning model (PjBL) for the creation of this water rocket also aims to create collaborative learning environment conditions. This can be shown by student activities through discussion activities to find and unite creative ideas to create the best water rocket product results.

Then, the hands-on experience that students experience can help transform learning materials that were initially only considered abstract into a more meaningful and deeply memorable understanding. For example, the moment when students successfully launch their homemade water rocket into the sky that can create the culmination of a cognitively and emotionally learning experience. Lesson theory that is initially considered a mere abstract can then turn into a real phenomenon that students experience directly, so that it can help create confidence in students that can give rise to a high sense of pride and enthusiasm.

This water rocket making activity effectively honed students' critical thinking skills. When students are faced with the challenge of determining the right volume of water or launch angle for the rocket to reach the maximum distance, they undertake a process of analysis, deduction, and evaluation. This critical thinking skill is honed when students try to connect abstract scientific concepts with real phenomena. Statistically, active involvement in these exploratory projects shows a consistent improvement in students' skills in systematically solving complex problems.

In addition, critical thinking skills can be strengthened or sharpened through the process of proving between the theory learned and the practice carried out. When students carry out self-proof activities directly, they not only receive information literally, but also need to conduct research first through deep thinking logic. Analysis and observation activities on water rocket test practices indirectly require students to think critically or think at a high cognitive level (HOTS).

This is in line with the results of the statistical test of the influence of the project learning model (PjBL) of water rocket making using an independent sample t-test which showed that the significance value (Sig.) obtained was 0.023. This value shows a number greater than the level of 0.05, so it can be concluded that the hypothesis in this study is accepted. With the acceptance of this hypothesis, it can be stated that there is a real difference in the results of critical thinking between students in the control class and the experimental class. This indicates that the treatment given to one group has a significantly different impact on students' critical thinking skills when compared to the other group.

From a pedagogical perspective, this learning event or activity will help change students' understanding from what was originally just a knowledge to a complete understanding. The subject matter studied can then be seen as a tool that can work or be practiced directly in the real world, for example in the manufacture of water rockets. Thus, it is the main basis that is very important in efforts to develop critical thinking skills. From this, it can be understood that the correlation lies in the shift in the role of students, when the material or explanation of lesson theory is understood or seen as a real tool, so that it can directly create a sense of ownership over control in the learning process or activity (sense of agency). The process of experimentation or experimentation when launching a water rocket encourages the growth of a sense of responsibility and confidence, where students learn to find solutions to technical obstacles they encounter in the field without relying entirely on the teacher's instruction. The growth of student learning independence occurs because students no longer need to wait for directions or theoretical instructions, but rather have the encouragement from themselves to be able to directly explore variables independently to find out the results according to what they want. Students become independent learners who can set up the design of methods and evaluate their learning progress based on the results of real experiences that students get firsthand.

Based on the results of the data analysis that has been carried out, it was found that the application of treatment in the experimental class has a significant impact on the development of students' character. The results of data analysis using parametric statistical tests showed that the significance value or Sig. (2-tailed) produced was 0.012. Given that this number is much smaller than the specified alpha threshold, which is 0.05 ($0.012 < 0.05$), a statistical decision was made that the null hypothesis (H0) was rejected and the alternative hypothesis (Ha) in this study was accepted. This led to the conclusion that there was a significant difference in average student independence outcomes between the control class and the experimental class after the intervention was administered. Empirically, these findings indicate that the treatment applied to the experimental group has succeeded in having a real impact in increasing student independence in a measurable way when compared to the control group.

Critical thinking skills and learning independence in elementary school students are two aspects of competencies that integrate with each other and create positive reciprocal relationships. Students who have high critical power will tend to be more independent because they have the cognitive foundation to analyze problems, evaluate options, and make decisions without always relying on the teacher's instruction. On the contrary, learning independence is a vehicle for students to practice their thinking skills freely through exploration and independent trials. In the context of water rocket making, the synchronization of these two aspects is seen when students independently take the initiative to make design improvements based on a critical analysis of the failure of previous launches. This synergy creates a continuous learning cycle, where sharpness of thought encourages autonomous action, and independence in acting will further sharpen students' logical acumen in solving more complex problems. In line with the results of statistical testing outputs to determine the strength and direction of the relationship between critical thinking and independence, it is known that the significance value or Sig. (2-tailed) obtained is 0.006. Since the value is smaller than the threshold of 0.05, it can be concluded that these variables are correlated, which means that there is a significant relationship between the critical thinking variable and the level of student independence. However, if reviewed from the results of the SPSS calculation, it was found that the correlation coefficient was 0.490. This coefficient number shows that the level of strength of the relationship between critical thinking and independence is actually in the category of moderate correlation relationships, which means that they are still interrelated or related between the variables of critical thinking ability and learning independence. While not "very strong," this figure proves that an increase in one variable tends to be followed by an increase in another consistently.

The success of the research is inseparable from several supporting factors that are in harmony between the learning methods used, the availability of learning media, and the enthusiasm of the research subjects. The use of project-based learning models (PjBL) combined with learning media such as water rockets is the main attraction because it can present science learning activities that are concrete (real) and creative (fun) for elementary school students. In addition, the availability of tools and materials used as learning media is very easy to obtain, and also the environment around the school is adjacent to a large field to conduct water rocket launch trials so that it can provide space for students to experiment more freely and freely. Then, support from the school and active involvement of students in every stage of the project from preparation, design, practice making, trial to analysis and evaluation of results are a provision of stimulus that can strengthen the process of internalizing learning independence and sharpen critical thinking skills in students. Collaboration between the availability of adequate facilities and access as well as any challenging instructional design to be able to ensure that every variable in the research is optimally observed and developed during the experimental activities.

The application of the project-based learning model (PjBL) through water rocket making activities is highly recommended in the learning curriculum, especially in elementary schools because it is able to integrate cognitive and character development on a continuous basis. In this activity, the aspect of students' critical thinking skills is honed through challenges that have a science learning design, where students will have to conduct studies related to the functional relationship between air pressure, water volume, and rocket stability to determine the best formulation in determining the optimal launch success.

In addition, this project-based learning model (PjBL) of water rocket making, can naturally foster motivation for independent learning because students are given the opportunity to be able to access the widest learning space in terms of independent decision-making, the right to autonomy to manage resources, and a sense of responsibility for every step in the project until optimal results are obtained.

In more depth, this project-based learning activity (PjBL) for making water rockets is highly recommended because it provides a learning environment that provides direct or real experiences (experimental learning). In the learning process, students not only learn theory in the abstract, but also directly involved in the cycle of design, testing, and evaluation independently which can train students' mental toughness when faced with technical problems. For teachers, by using this project-based learning model (PjBL), teachers become the main facilitator instead of the main source of information that can make students dependent on teachers, so that it can help motivate students to be able to become lifelong learners who have optimal critical thinking skills and can act independently in learning.

Research Limitations

A series of research activities have been carried out in accordance with the procedures and provisions, and have produced relevant findings so that they can explain and provide an overview of the Influence of Project-Based Learning of Water Rocket Making on the Learning

Independence and Critical Thinking of Elementary School Students. However, this research still has some limitations that need to be considered again, especially as a reference material that has strong validity for future research so that it can produce even better research.

The implementation of manufacturing practices to test launches of water rockets encountered a number of technical obstacles stemming from limited duration and external environmental factors. The available time allocation is considered insufficient to cover all stages of production, from precise rocket body assembly to wing adjustment, so some technical details do not have time to be perfected to the maximum.

The situation at the test site also presents its own challenges, especially related to wind gusts that are dynamic enough to affect the aerodynamic stability of the rocket when launching. In addition to weather factors, uneven field surface conditions and exposure to sunlight also affect the process of adjusting the position of the launcher. These things technically have an impact on the variation in the mileage and accuracy of the rocket landing in each test session.

In addition to technical and environmental constraints, other challenges arise from the aspect of initial understanding of students who are mostly unfamiliar with the concept and mechanism of water rockets. For many students, this is their first experience directly interacting with science props that use the principle of air and water pressure, so it takes extra time to understand how components such as nozzles, fin functions, and locking techniques on pumps work. This unfamiliarity leads to the emergence of doubts in the early stages of practice, where students need more intensive mentoring to ensure they can operate the launcher safely and precisely. As a result, the exploration phase that should have been able to run faster became a little hampered because students had to first adapt to tools and materials that they had never encountered before in the school environment.

The practice of making and testing water rockets for elementary school students often faces technical and operational obstacles due to limited motor skills and understanding of basic physics concepts. In the manufacturing stage, the most common problems that arise are difficulties in maintaining precision, such as the installation of fins that are not aligned or tilted due to the use of less strong glue, which results in an unstable or rotating flight path of the rocket. In addition, students often have difficulty in making airtight connections on the nozzle, resulting in pressure leaks during the pumping process that cause the rocket to fail to glide at maximum power.

During the trial stage in the field, the main obstacles faced by elementary school students were pressure management and water ratio. It is often found that rockets filled with water are too full due to the enthusiasm of the students, which actually makes the rocket too heavy to be lifted by the thrust. In addition, coordination when pulling the trigger mechanism is often an obstacle; Students sometimes feel afraid or hesitant when the pump is already heavy, so the pressure produced is inconsistent. From an environmental perspective, wind factors and narrow launch locations are also a challenge, where rockets often get stuck in trees or buildings due to less aerodynamic fin design or improper launch angles.

Apart from the various obstacles faced during the experimental process, the findings in the study entitled "The Effect of Project-Based Learning of Water Rocket Making on the Learning Independence and Critical Thinking of Elementary School Students" continue to make a significant scientific contribution. The results of this study have succeeded in proving that the integration of the Project-Based Learning (PjBL) model through the water rocket project is an effective instructional strategy to stimulate students' independence and critical power at the basic education level. The design and launch activities of water rockets are not only an innovative learning medium, but also a real science exploration vehicle for students.

However, in order to achieve a broader and more precise generalization of results, future research needs to consider several aspects. It is necessary to support the availability of more uniform support facilities for each group of students and more adequate adaptation time so that students can internalize project procedures in depth. In addition, stability of environmental factors and more intensive monitoring of the collaboration process are needed to obtain more comprehensive data, so that the effectiveness of the PjBL model can be more accurately described in the context of improving the quality of science education in elementary schools.

CONCLUSION

Based on the research findings, it was concluded that the implementation of the Project-Based Learning (PjBL) model through water rocket construction had a positive and significant effect on elementary school students' critical thinking skills and learning independence. The analysis results showed significant differences between the experimental and control groups in critical thinking skills ($p = 0.023 < 0.05$) and learning independence ($p = 0.012 < 0.05$), indicating that project-based learning improved both aspects more effectively than conventional learning methods. Furthermore, a significant relationship was identified between critical thinking skills and learning independence, with a correlation coefficient of 0.490, which was categorized as moderate. This finding suggested that improvements in critical thinking skills were accompanied by increases in students' learning independence. Based on these results, teachers are encouraged to optimize the use of the PjBL model through contextual and engaging projects, such as water rocket construction, while schools and educational authorities should provide support through teacher training, adequate facilities, and learning environments that facilitate project-based instruction. Future research is recommended to examine additional variables, such as creativity and collaboration skills, with broader research contexts and participants. Practically, water rocket projects can serve as an affordable, engaging, and effective alternative for science learning to develop 21st-century skills, particularly critical thinking skills and learning independence among elementary school students.

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