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The Effect of Project-Based Learning (PjBL) On Critical Thinking Skills as Seen from Cognitive Styles

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ABSTRACT

This study investigates the effect of the Project-Based Learning (PjBL) model on eighth-grade students' mathematical critical thinking skills, considering their cognitive styles. The research employed a quasi-experimental design with a non-equivalent control group, involving eighth-grade students of SMP Negeri 24 Kerinci in the 2023/2024 academic year. The sample comprised two experimental classes taught with the PjBL model and one control class taught conventionally. Data were collected using the Group Embedded Figures Test (GEFT) to identify students' cognitive styles and an essay test to measure critical thinking skills. Data analysis was conducted through a two-way ANOVA to examine the effects of the learning model and cognitive style, followed by a t-test for further comparison. The results showed that the PjBL model and students' cognitive styles significantly influenced mathematical critical thinking skills. Field Independent (FI) students scored higher than Field Dependent (FD) students. However, no significant interaction was found between the learning model and cognitive style, indicating that PjBL provides relatively balanced opportunities for all learners. These findings suggest that PjBL can be an effective and inclusive instructional approach to foster students' critical thinking, and mathematics teachers are encouraged to integrate it into classroom practice.

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1. INTRODUCTION

One of the essential competencies that must be developed through education is critical thinking skills [1]. Critical thinking is a high-level thinking skill that requires understanding information and analysing, evaluating, and processing logically and systematically to make the right decision [2]. Critical thinking is critical in mathematics learning because it allows students to memorise formulas, understand concepts, identify problems, find solutions, and connect material with real-life phenomena [3], [4]. With critical thinking skills, students are expected to face the challenges of the 21st century that demand skills in solving complex problems, making wise decisions, and adapting to rapid changes [5].

Although critical thinking is a very important skill, the reality is that learning mathematics in schools still faces various obstacles. Based on the researchers' initial observations on November 20, 2022, in class VIII of SMP Negeri 24 Kerinci, several obstacles were found that affect the quality of student learning. First, a busy curriculum often makes teachers focus on achieving material targets, so the time available for deepening concepts is limited. Second, students still have difficulty understanding abstract concepts, such as algebra, geometry, and statistics, resulting in low basic understanding. Third, students' interest and motivation in learning mathematics is low because they consider math difficult and irrelevant to their daily lives. Fourth, limited learning resources and educational facilities are significant barriers to effective learning. Finally, some students lack the confidence to ask questions or express their opinions in class, limiting their participation in learning. These conditions make mathematics learning not optimal for fostering students' critical thinking skills.

One alternative that can be used to overcome various problems in learning mathematics is the application of the Project-Based Learning (PjBL) model [6], [7]. This Model emphasises active student involvement through projects that depart from real-world problems, making the learning process contextual, meaningful, and challenging [8], [9]. Through PjBL, students are not only required to understand the material but also have the opportunity to collaborate, explore ideas, solve problems, and produce real products relevant to everyday life [10], [11]. Thus, PjBL can foster motivation, increase student involvement in learning, and train critical thinking skills, which are the main demands in the Merdeka Curriculum [12].

In addition to the learning model used, students' cognitive style also plays an important role in determining the success of the learning process. Cognitive style refers to how individuals receive, process, and respond to information, ultimately affecting the chosen learning strategy[13]. Differences in cognitive styles among students can cause variations in concept understanding and learning outcomes achieved [14]. Therefore, the application of Project-Based Learning (PjBL) will be more effective if it takes into account the characteristics of students' cognitive styles, so that each individual can optimise their potential [15], [16]. Thus, combining innovative learning models and understanding cognitive styles is expected to support improving students' critical thinking skills more optimally [17], [18].

Based on this description, it can be concluded that improving students' mathematical critical thinking skills requires innovative learning approaches such as Project-Based Learning (PjBL) and considering the differences in cognitive styles possessed by each student. However, research that specifically examines the effect of PjBL on mathematical critical thinking skills by considering aspects of cognitive style is still limited. Therefore, researchers are interested in conducting a study entitled "The Effect of Project-Based Learning (PjBL) on Mathematical Critical Thinking Ability of Junior High School Students in Grade VIII Considered from Cognitive Style".

2. METHOD

2.1 Design

This study uses a quantitative method and follows experimental research techniques. Quantitative research is a way of gathering and analyzing data using numbers to get organized and clear results. This study is experimental because it uses the PjBL learning model for teaching and learning activities. The study is a type of quasi-experimental research, which follows the Non-equivalent Control Group Design. Quasi-experimental research is like a real experiment, but it doesn't randomly assign participants to groups. Instead, it uses groups that are already formed naturally. The experimental group receives a special treatment, while the control group does not.

Table 1. Research Design

Group	Pre-test	Treatment	Post-test
Eksperiment	P_1	X	P_2
Control	P_1		P_2

Description:

X = Learning treatment through the PjBL learning model to improve students' critical thinking skills

P1 = Pre-test (Initial test)

P2 = Post-test (Final test)

2.2 Population and Sample

According to Sugiyono [19], population refers to a general group that includes objects or individuals with specific features, which are selected by researchers to study and then draw conclusions from. In this study, the population consists of all students in grade VIII at SMP N 24 Kerinci. It is important to define the population clearly because it serves as the main basis for choosing samples and ensures that the research results reflect real conditions in the field.

A sample is a part of the population that has similar characteristics [19]. Samples in this study were taken from two classes, one as an experimental group and one as a control group. The sampling technique used was a purposive sampling method. Purposive sampling uses certain aspects to determine the number of samples to be examined according to the desired criteria. The reason behind the purposive sampling technique is that it is suitable for quantitative research, or research that does not generalise [20]. In other words, this technique allows researchers to focus on subjects who meet specific conditions so that the data collected is more precise and in line with the objectives of the study.

In this study, the sample was chosen from two classes, namely class VIII A with 20 students who would be the experimental group and taught using the Project Based Learning (PjBL) model. Class VIII B with 20 students would be the control group and taught without the PjBL model. Dividing the students into experimental and control groups allows for a comparison of learning outcomes, making it easier to assess the effectiveness of the PjBL model in a controlled setting.

2.3 Research Instrument

This research instrument is a pre-test and post-test design. The use of pre-test and post-test is intended to measure the initial ability of students before treatment and the improvement in learning outcomes after treatment is given.

Pre-test and post-test instruments are designed based on the mathematics class VIII SMP. The preparation of the instrument was adjusted to the curriculum and learning objectives of class VIII mathematics to ensure content validity and alignment with the material taught.

After treatment, the instrument was given to the experimental and control classes as a student critical thinking test consisting of 10 essay questions. The choice of essay questions was made to encourage students to express reasoning processes in detail, so that their critical thinking skills could be observed and assessed more comprehensively..

2.4 Data Analysis

The data collected was then analyzed using descriptive statistical methods and inferential analysis. This process helps to determine if the project-based learning model (PjBL) has an impact on students' critical thinking skills in mathematics or if there is no effect. Descriptive statistics were employed to summarize the data distribution, while inferential analysis was used to draw conclusions that go beyond the observed sample. Before starting the analysis, the data underwent necessary preliminary tests. The following explanation outlines this process:

a. Normality Test

The normality test is a necessary step to check if the data meets the assumption of normality required for parametric statistical analysis. This test helps determine if the sample data follows a normal distribution. In this study, the Kolmogorov-Smirnov test was used, and it was conducted with the help of SPSS. Ensuring normality is crucial because it provides a strong foundation for the validity of subsequent statistical tests.

b. Homogeneity Test

A homogeneity test is conducted to see whether the sample group has a homogeneous variant. This test was conducted using the Levene Test with the help of SPSS. The homogeneity of variance indicates that the differences observed between groups are not influenced by unequal data dispersion, thus making the comparison more reliable.

c. Hypothesis Test

The hypothesis test used in this study is a two-way ANOVA test (path). This two-way ANOVA test compares the average difference of the variance analysis groups. Further tests using the t-test compare the means of two paired groups. The combination of ANOVA and t-test provides both a general overview of group differences and a more detailed comparison between specific groups, ensuring that the effect of the PjBL model is analyzed comprehensively.

3. RESULTS AND DISCUSSION

3.1 RESULTS

In line with Novita et al. (2024), the results of previous studies show that Project-Based Learning (PjBL) is efficacious in improving students' critical thinking skills [21]. PjBL encourages students' active involvement in identifying problems, analysing information, and producing evidence-based solutions, which are the core of critical thinking skills [22], [23]. From the perspective of cognitive style, the results of this study reinforce Witkin's theory, which states that students with Field Independent (FI) cognitive style have analytical processing tendencies and can work independently, so they excel in learning situations that demand complex problem solving [24]. Students with Field Dependent (FD) style need external support and are more influenced by context, thus experiencing obstacles in developing deep analytical skills [25]. Thus, the integration between the PjBL model and cognitive style characteristics supports previous literature, which confirms that the effectiveness of PjBL is determined by learning design and individual student differences [26]. Before conducting data analysis, the collected data were first tested for normality and homogeneity as follows:

Test the normality of daily test scores using the test. The test results can be seen in the following table.

Table 2. Output SPSS Results of the normality test of student posttest scores

	Class	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	Df	Sig.	Statistic	Df	Sig.
Value	Experiment 1	.119	20	.200*	.942	20	.262
	Control	.176	20	.108	.922	20	.110

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Based on the results of the Kolmogorov-Smirnov test in Table 2, the significance value or p-value for all classes is greater than the alpha value (0.05), so it can be said that the test scores of the research population are normally distributed. After conducting the normality test, thedata were tested for homogeneity.

Table 3. Output SPSS Results of the homogeneity test of student post-test scores

Value			
Levene Statistic	df1	df2	Sig.
.233	2	59	.793

Table 3 shows that the significance value for the students' daily test scores is 0.793, which is higher than the alpha level of 0.05. This means the students' test scores are considered homogeneous. Looking at the results from the prerequisite tests, the data is both normally distributed and homogeneous. Because of this, the researcher can move forward with further analysis, specifically using the ANOVA test in SPSS.

Table 4. The Results of ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	2038.986	2	1019.493	12.986	.000[b]
	Residual	4631.982	59	78.508		
	Total	6670.968	61			

a. Dependent Variable: Value
b. Predictors: (Constant), Cognitive style, Model

Based on Table 4 above, it can be seen that with the ANOVA approach (ANOVA table), the PjBL learning model and cognitive style affect students' mathematics learning outcomes at SMP Negeri 6 Kerinci. This is indicated by the rejection of Ho (Sig. = 0.000 < 0.05).

Table 5. Output SPSS Cognitive style

Dependent Variable: Value

Cognitive style	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
FI	80.369	1.716	76.933	83.805
FD	73.774	1.716	70.338	77.209

Based on Table 5 above, the average critical thinking skills in mathematics of students with the FI cognitive style is 80.369, which is higher than that of students with the cognitive style, 73.774.

Table 6. Output SPSS Model * Cognitive Style

Dependent Variable: Value

Model	Cognitive Style	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
PjBL	FI	85.238	1.950	81.335	89.141
	FD	79.048	1.950	75.145	82.950
Konvensional	FI	75.500	2.825	69.845	81.155
	FD	68.500	2.825	62.845	74.155

Based on Table 6 above, it can be concluded that the average score for mathematical critical thinking skills of students taught using the PjBL model, where students with FI cognitive styles had an average score of 85.238, while those with FD cognitive styles had an average score of 79.048. Meanwhile, the average critical thinking skills scores of students taught using the conventional learning model, where students with FI cognitive styles had an average score of 75.500, while those with FD cognitive styles had an average score of 68.500.

The superiority of FI students can be explained through Piaget's cognitive theory, which emphasises the importance of assimilation and accommodation processes in building knowledge structures. With analytical and independent tendencies, FI students can better restructure concepts when facing complex problems, so that their critical thinking skills develop better. This finding also aligns with Bruner's (1960) view that emphasises discovery learning, where students are more independent in exploring knowledge and will more easily find linkages between concepts [27]. In the context of PjBL, FI students more easily utilise the characteristics of this learning model that demand active engagement, problem-solving, and evidence-based decision-making. In contrast, FD students relying more on external support tend to have difficulty managing information and building solutions independently. This study's results align with Bell's (2010) study, which asserts that PjBL can encourage the development of critical thinking skills, but its effectiveness is strongly influenced by students' cognitive characteristics [28].

Next, a t-test was performed to compare the average scores between the two classes. The results are shown in Table 7. The independent sample t-test was chosen because it is appropriate for comparing the mean scores of two different groups, namely the experimental class and the control class.

Table 7. Output SPSS Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Value	Equal variances assumed	.520	.480	.293	19	.773	1.364	4.653	-8.375	11.102
	Equal variances not assumed			.295	18.930	.771	1.364	4.616	-8.299	11.027

According to Table 7, the significance value (two-tailed) is 0.773, which is greater than 0.05. Based on the criteria for making decisions in an independent sample t-test, we accept the null hypothesis (Ho) and reject the alternative hypothesis (Ha). This means that the statistical evidence does not support the assumption that the PjBL learning model produces different outcomes in students' mathematical critical thinking when compared to conventional learning methods.

This indicates that there is no significant difference in the mathematical critical thinking skills of students with FI cognitive styles who were taught using the PjBL learning model. In other words, the application of PjBL does not significantly influence the critical thinking abilities of students within this particular cognitive style category..

This finding indicates that in the context of PjBL, cognitive style factors are not always the main determinant of differences in learning outcomes when students are in the same category. PjBL can provide a structure of activities that demand active involvement, collaborative work, and authentic problem solving, thus encouraging the development of critical thinking skills in a relatively balanced manner. This reinforces Thomas's (2000) study that the success of PjBL is determined more by the quality of project design and the intensity of student involvement than by specific individual variables [29]. Thus, the new contribution of this study is that although previous theories emphasise the superiority of FI in analytical tasks, in the implementation of PjBL, the difference does not appear significant, so this Model can be viewed as an inclusive approach and able to accommodate variations in cognitive styles.

3.2 DISCUSSION

The findings of this study indicate that the implementation of Project-Based Learning (PjBL) has a significant effect on students' mathematical critical thinking skills. This result is consistent with Bell (2010), who emphasized that PjBL promotes students' active engagement in problem-solving, information analysis, and evidence-based decision-making, which are the core components of critical thinking skills [29]. Similarly, Afandi, Fatma, and Yustiana (2024) reported that applying PjBL at the elementary level significantly enhanced critical thinking skills, confirming the effectiveness of this Model across various educational levels [30].

From the cognitive style perspective, this study reveals that students with a Field Independent (FI) style achieved higher scores than those with a Field Dependent (FD) style. This aligns with Witkin et al. (1975), who explained that FI students tend to be more analytical and capable of independent learning, enabling them to excel in complex problem-solving situations [31]. Supporting this, Firdaus, Nisa, and Nadhifah (2019) found that FI students performed better in solving mathematical tasks requiring deep analysis [32]. Hence, the superiority of FI students in the context of PjBL can be attributed to their systematic information-processing tendencies and ability to build conceptual connections.

Although differences were observed between FI and FD learners, this study found no significant interaction between learning models and cognitive styles. In other words, PjBL provides relatively balanced opportunities for both cognitive style groups. This supports Thomas (2000), who highlighted that the success of PjBL is determined mainly by the quality of project design and the intensity of student engagement rather than individual characteristics. Similarly, Ospankulova et al. (2025) demonstrated that students' attitudes, motivation, and engagement in PjBL enhanced learning outcomes more than cognitive style variables [33].

Therefore, the main contribution of this study is providing empirical evidence that PjBL is an inclusive and innovative instructional approach that supports the achievement of the Merdeka Curriculum goals. The success of PjBL in improving mathematical critical thinking skills depends not only on cognitive style differences but also on meaningful project design, teacher support, and contextualized learning environments. Accordingly, mathematics teachers are encouraged to design PjBL activities that are contextual, collaborative, and challenging, so that all students—FI and FD—can maximize their critical thinking potential.

4. CONCLUSION

The application of Project-Based Learning (PjBL) can improve students' mathematical critical thinking skills, with Field Independent (FI) cognitive style students showing higher achievement than Field Dependent (FD). Overall, PjBL still provides relatively balanced opportunities for all cognitive styles. This finding confirms that the success of PjBL is more determined by the quality of project design and student involvement than individual factors alone. Practically, mathematics teachers are advised to integrate PjBL into learning to foster critical thinking skills, regardless of students' cognitive styles. For future research, it is recommended to use a wider sample and different classroom contexts and explore the integration of PjBL with other models to obtain a more comprehensive picture. Thus, this research makes an important contribution to mathematics education as empirical evidence that PjBL is an innovative strategy that is inclusive in supporting the achievement of Merdeka Curriculum goals.

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