



# Implementation of Project-Based Learning to Improve Students' Critical and Collaborative Thinking Skills in Database Subjects in the Independent Curriculum

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## ABSTRACT

### Keywords:

Project-Based Learning, critical thinking skills, collaborative abilities, Merdeka Curriculum, vocational education

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This study investigates the effect of the Project-Based Learning (PjBL) model on students' critical thinking skills, with collaborative ability acting as an intervening variable, in the context of the Merdeka Curriculum for the Database subject in vocational education. This research was conducted at SMKN 6 Kupang involving 60 eleventh-grade students of the Software and Game Development (PPLG) program. A quantitative approach was employed using path analysis to examine both direct and indirect relationships among variables. The findings of Model 1 indicate that the PjBL model has a significant positive effect on students' collaborative ability ( $\beta = 0.390$ ,  $p < 0.05$ ), explaining 15.2% of the variance. Furthermore, Model 2 reveals that the PjBL model significantly influences students' critical thinking skills both directly and indirectly through collaborative ability. Collaborative ability was found to have a significant effect on critical thinking skills and partially mediates the relationship between PjBL and critical thinking. These results suggest that PjBL not only directly enhances students' critical thinking skills but also strengthens them indirectly by fostering effective collaboration during project implementation. Therefore, the integration of PjBL in vocational learning, particularly in Database subjects, is effective in supporting the development of critical thinking and collaborative competencies required in 21st-century learning and the Merdeka Curriculum framework..

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## INTRODUCTION

Critical thinking is widely recognized as a fundamental competence required to face the complex challenges of the 21st century, including rapid technological change, digital transformation, and increasingly complex social and economic problems (Bernotaite & Karseth, 2025; Mertanen & Brunila, 2024). The ability to critically analyze information, evaluate evidence, and synthesize

solutions is essential not only for academic success but also for informed citizenship and workforce readiness. Empirical evidence from international assessments such as PISA indicates that many students still struggle to apply higher-order thinking skills in authentic contexts, particularly in problem-solving and decision-making tasks (Bernotaite & Karseth, 2025; Mertanen & Brunila, 2024). This condition highlights a gap between educational outcomes and societal demands. Consequently, education systems must prioritize instructional approaches that foster higher-order thinking skills. From a societal perspective, strengthening students' critical thinking abilities contributes to the development of a competent, adaptable, and innovative workforce, which is crucial for sustainable development and social resilience in the digital era (Kusumawati, Rahma, et al., 2025; Kusumawati, Rahman, et al., 2025).

Despite the growing emphasis on higher-order thinking skills, many educational practices remain dominated by teacher-centered instruction and rote learning, which primarily promote lower-level cognitive skills (Aashamar et al., 2024; Heffington & Coady, 2023). In vocational education, this issue becomes more pronounced because students are expected to apply knowledge directly to real-world work situations. However, learning activities often focus on procedural mastery rather than analytical reasoning, evaluation, and problem-solving. Higher-order thinking involves the ability to make inferences, interpret implicit meanings, and construct knowledge that extends beyond explicitly presented information. When instructional strategies fail to support these processes, students' critical thinking development remains limited. This pedagogical gap reflects a broader systemic challenge in aligning curriculum goals, instructional methods, and assessment practices (Aini et al., 2025; Fauzi et al., 2025). As a result, students may graduate with technical skills but lack the cognitive flexibility and reasoning abilities required by modern industries. Addressing this problem requires innovative learning models that actively engage students in complex, meaningful learning experiences.

In the context of vocational high schools, particularly in database subjects, students are required to demonstrate strong critical thinking and collaboration skills when designing database systems, analyzing user needs, and solving data-related problems (Abas & Kholidah, 2025; Fajariyah, 2025). However, preliminary observations indicate that many students experience difficulties in analyzing problems deeply, integrating concepts, and working effectively in teams (Windiasari et al., 2025; Yakin et al., 2025). Collaborative activities often tend to be superficial, with uneven task distribution and limited meaningful interaction among group members. These challenges are exacerbated in regions such as East Nusa Tenggara (NTT), where disparities in educational infrastructure, access to technology, and teacher professional development persist. Previous studies on active and vocational learning suggest that such contextual constraints significantly influence the effectiveness of innovative

instructional models (Assaf, 2023; Sarney et al., n.d.). This field phenomenon underscores the need for empirical investigation into instructional approaches that can simultaneously enhance critical thinking and collaboration skills within the specific realities of vocational education settings.

Previous research has consistently identified Project Based Learning (PjBL) as an instructional model capable of fostering higher-order thinking skills, including critical thinking (Almazroui, 2023; Artama et al., 2023). PjBL emphasizes student-centered learning through engagement in authentic, context-rich projects that require inquiry, analysis, and reflection. Studies have shown that students involved in PjBL demonstrate improved problem-solving abilities and deeper conceptual understanding compared to those in traditional instructional settings. From a cognitive perspective, PjBL aligns with the higher-order thinking framework proposed by (Heffington & Coady, 2023) and (Aashamar et al., 2024), as it encourages students to interpret information, analyze relationships, and construct knowledge meaningfully. However, much of the existing literature focuses on general education contexts, with limited attention to vocational subjects such as database systems (Jasri, 2025; Pratama, 2025). Moreover, many studies examine critical thinking outcomes without considering social and collaborative processes that may mediate learning effectiveness.

Collaboration is another essential 21st-century skill that plays a critical role in supporting higher-order thinking processes (Adl-Amini et al., 2024; Tadesse et al., 2024). Collaborative learning enables students to exchange ideas, negotiate meaning, resolve conflicts, and co-construct knowledge, which in turn enhances critical thinking development (Barokah, 2025; Muharromah & Manshur, 2025). Within PjBL environments, collaboration is a core component, as project success depends heavily on effective teamwork. Nevertheless, empirical studies examining collaboration as an intervening or mediating variable in the relationship between PjBL and critical thinking remain limited, particularly in vocational education contexts. Existing research often treats collaboration as a secondary outcome rather than a key explanatory mechanism. This gap indicates a need for studies that explicitly investigate how collaborative skills influence the effectiveness of PjBL in enhancing critical thinking. Addressing this gap will contribute to a more comprehensive understanding of learning dynamics in project-based vocational education.

The novelty of this study lies in its integrative approach that examines the effect of Project Based Learning on students' critical thinking skills by positioning collaboration ability as an intervening variable within a vocational education context. Unlike previous studies that primarily focus on direct effects, this research emphasizes the mechanism through which PjBL influences cognitive

outcomes. Furthermore, this study is situated within the implementation of Indonesia's Merdeka Curriculum, which promotes flexible, contextual, and competency-based learning approaches. By focusing on database subjects in vocational high schools located in resource-limited regions, this research provides empirical evidence that is both context-sensitive and policy-relevant. The study contributes to the state of the art by bridging theoretical perspectives on higher-order thinking with practical instructional challenges in vocational education, particularly in underdeveloped regions facing digital and infrastructural constraints.

Based on the theoretical framework and empirical gaps identified, this study investigates the effect of Project Based Learning on students' critical thinking skills with collaboration ability as an intervening variable in database learning at SMKN 6 Kupang. The central argument of this research is that PjBL positively influences critical thinking not only through active engagement with authentic problems but also through enhanced collaborative processes among students. It is hypothesized that students who demonstrate stronger collaboration skills will experience greater gains in critical thinking within PjBL environments. The findings of this study are expected to contribute both theoretically and practically. Theoretically, the study enriches the discourse on higher-order thinking development by integrating cognitive and social dimensions of learning. Practically, it provides evidence-based recommendations for teachers, school leaders, and policymakers in designing effective, inclusive, and context-appropriate project-based learning strategies in vocational education.

## RESEARCH METHOD

The unit of analysis of this study refers to the learning process and students' competencies in the implementation of Project Based Learning (PjBL) in the Database subject at SMKN 6 Kupang. The research focuses on a specific educational setting, namely a vocational high school, involving students of Grade XI in the Software and Game Development (PPLG) program who had previously experienced PjBL-based instruction. The research design employed a quantitative approach using an analytical survey with an ex post facto design. This design was selected because the study aimed to examine the relationships and causal effects among variables based on existing conditions, without manipulating the independent variables. The research analyzed the direct effect of PjBL on students' critical thinking skills as well as its indirect effect through students' collaboration ability as an intervening variable.

The sources of information in this study consisted primarily of respondents, namely 60 students who constituted the entire population and were therefore selected using a saturated sampling technique. Data were collected

through multiple methods to ensure comprehensive measurement of the research variables. The data collection process involved the use of tests to measure students' critical thinking skills, questionnaires to assess students' collaboration ability, and observations to describe the implementation fidelity of the PjBL model in classroom practice. The instruments used in this study had been subjected to validity and reliability testing prior to data collection to ensure the accuracy and consistency of the measurements. Observational data supported the quantitative findings by providing contextual information regarding the learning process.

The data analysis was conducted using path analysis to examine both direct and indirect relationships among the independent, intervening, and dependent variables within an integrated analytical model. Although this study adopted a quantitative approach, the analytical procedure followed systematic stages, including data screening, model specification, and verification of causal relationships. Path analysis was chosen because it allows for a comprehensive examination of causal structures among multiple variables simultaneously. All statistical analyses were performed using appropriate statistical software to ensure precision and reliability of the results. This analytical approach enabled the study to provide empirical evidence regarding the role of collaboration ability in mediating the effect of PjBL on students' critical thinking skills.

### **Research Variables**

The variables in this study consist of independent variables, dependent variables, and intervening variables, which are explained as follows:

#### **Independent Variable (X1):**

An independent variable is a variable that influences or causes changes in another variable. In this study, the independent variable is the Project-Based Learning (PjBL) model. PjBL is defined as a learning model that emphasizes active student involvement in designing, implementing, and evaluating learning projects based on real-world problems.

#### **Dependent Variable (Y):**

The dependent variable in this study is students' critical thinking skills, namely students' abilities to analyze problems, evaluate information, draw conclusions, and make decisions logically and reflectively in Database learning.

#### **Intervening Variable (X2):**

An intervening variable is a variable that acts as an intermediary in the relationship between the independent variable and the dependent variable. In this study, the intervening variable is students' collaborative skills, namely the students' ability to work together effectively in groups, including communication, task division, responsibility, and conflict resolution in the

project-based learning process.

The ability to collaborate in this study is positioned as a variable that strengthens the influence of the PjBL learning model on students' critical thinking abilities, both directly and indirectly. Figure 1 explains the variables and relationships between variables in this study.

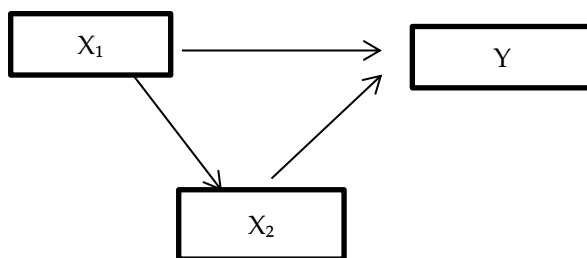


Figure 1. Relationship between Variables

Based on the relationship between the variables, the hypothesis in this research is as follows:

- H<sub>1</sub>:** There is a significant influence between the Project Based Learning model ( $X_1$ ) on students' critical thinking abilities ( $Y$ ).
- H<sub>2</sub>:** There is a significant influence between the Project Based Learning ( $X_1$ ) learning model and students' collaboration skills ( $X_2$ ).
- H<sub>3</sub>:** There is a significant influence between students' collaboration ability ( $X_2$ ) and students' critical thinking ability ( $Y$ ).
- H<sub>4</sub>:** Collaboration ability ( $X_2$ ) acts as an intervening variable in the relationship between the Project Based Learning model ( $X_1$ ) and students' critical thinking abilities ( $Y$ ).

## RESULT AND DISCUSSION

### RESULT

#### Path Coefficient of Model I

Testing with SPSS obtained the following results:

Table 1. Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Standard Error of the Estimate
1	.390 <sup>a</sup>	.152	.138	9,457

a. Predictors: (Constant), PjBL Model

#### Coefficients<sup>a</sup>

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1	(Constant)	20,843	7,567	2,755	.008
	PjBL Model	.478	.148	.390	.002

**a. Dependent Variable: Collaboration Ability**

Referring to the output of Regression Model I in the Coefficients table section, it can be seen that the significant value of the variable, namely  $X1 = 0.002$ , is smaller than 0.05. This result provides the conclusion that Regression Model I, namely variable  $X1$  has a significant effect on  $X2$ . The value of  $R^2$  or R Square contained in the Model Summary table is 0.152, this shows that the contribution or contribution of the influence of  $X1$  on  $X2$  is 15.2% while the remaining 84.8% is the contribution of other variables not included in the study. Meanwhile, the value of  $e1$  can be found with the formula  $e1 = \sqrt{1-0.152} = 0.9208$ . Thus, the path diagram of the structural model I is obtained as follows:

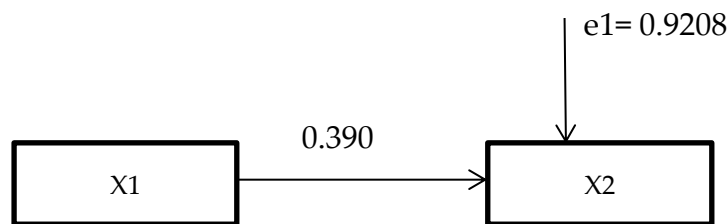


Figure 1. Path Coefficients of Model 1

**Path Coefficient of Model II**

The results of the data analysis carried out to test the second path obtained:

Model Summary				
Model	R	R Square	Adjusted R Square	Standard Error of the Estimate
1	.608 <sup>a</sup>	.370	.348	8.111

**a. Predictors: (Constant), Collaboration Ability, PjBL Model**

Model	Coefficients <sup>a</sup>			t	Sig.
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta		
1	(Constant)	43,983	6,902	6,373	.000
	PjBL Model	.457	.138	.379	.002
	Collaboration Skills	.345	.113	.350	.003

**a. Dependent Variable: Critical Thinking Skills**

Based on the output of Regression Model II in the Coefficients table section, it is known that the significant value of the two variables, namely  $X_1 = 0.002$  is smaller than 0.005 and  $X_2 = 0.003$  is also smaller than 0.05. These results provide the conclusion that Regression Model II, namely variables  $X_1$  and  $X_2$  simultaneously have a significant effect on  $Y$ . The value of R Square contained in the Model Summary is 0.370, this shows that the contribution of  $X_1$  and  $X_2$  to  $Y$  is 37% while the remaining 63% is the contribution of other variables not studied. Meanwhile, the value of  $e_2 = \sqrt{1-0.370} = 0.7937$ . Thus, the path diagram of the structural model II is obtained as follows:

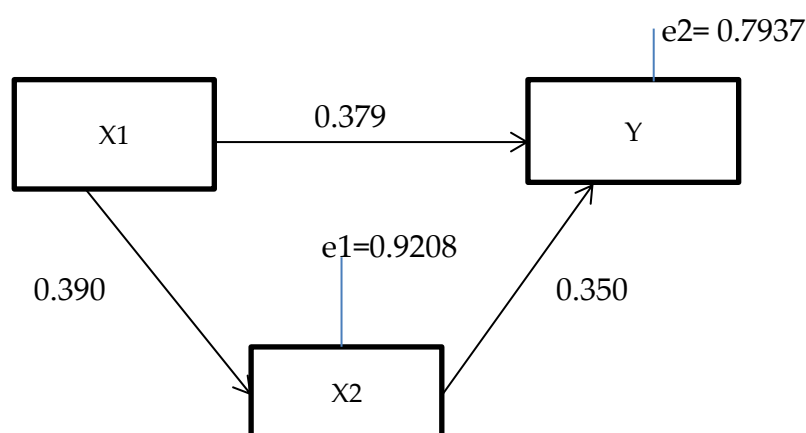


Figure 2. Path Coefficients of Model 2

## Research Hypothesis Testing

### Hypothesis Testing 1 ( $H_1$ )

**$H_1$ : There is a significant influence between the *Project Based Learning* ( $X_1$ ) learning model and students' critical thinking abilities ( $Y$ ).**

Based on the path analysis results in Model 2, the path coefficient value obtained indicates that the Project Based Learning (PjBL) learning model has a positive and significant effect on students' critical thinking skills. A significance value of less than 0.05 indicates that  $H_1$  is accepted. This finding indicates that the implementation of PjBL can improve students' abilities in analyzing problems, evaluating information, and formulating logical solutions through project-based learning activities.

### Hypothesis Testing 2 ( $H_2$ )

**$H_2$ : There is a significant influence between the *Project Based Learning* ( $X_1$ ) learning model and students' collaboration skills ( $X_2$ ).**

The results of the analysis in Model 1 show that the PjBL learning model has a positive and significant influence on students' collaboration abilities, with

a path coefficient value of  $\beta = 0.390$  and a significance value of  $p < 0.05$ . The contribution of the influence indicated by the  $R^2$  value of 0.152 indicates that PjBL explains 15.2% of the variation in students' collaboration abilities. Thus,  $H_2$  is accepted. This confirms that PjBL encourages students to work together actively, share roles, and take responsibility in completing learning projects.

### **Hypothesis Testing 3 ( $H_3$ )**

**$H_3$ : There is a significant influence between students' collaboration ability ( $X_2$ ) and students' critical thinking ability ( $Y$ ).**

Based on the results of the Model 2 analysis, students' collaborative skills were shown to have a positive and significant effect on their critical thinking skills. The statistical significance value, which met the statistical criteria, indicated that the better students' collaborative skills, the higher their critical thinking skills demonstrated in the learning process. Therefore,  $H_3$  was accepted. This finding reinforces the view that group discussions, idea exchange, and teamwork play a crucial role in developing higher-order thinking skills.

### **Hypothesis Testing 4 ( $H_4$ )**

**$H_4$ : Collaboration ability ( $X_2$ ) acts as an intervening variable in the relationship between the *Project Based Learning model* ( $X_1$ ) and students' critical thinking abilities ( $Y$ ).**

The path analysis results show that the PjBL model significantly influences students' critical thinking skills, both directly and indirectly through collaboration skills. The indirect effect formed through the collaboration variable strengthens the relationship between PjBL and critical thinking skills, while the direct effect remains significant. Thus, collaboration skills are proven to act as a partial intervening variable. Therefore,  $H_4$  is accepted. This finding indicates that the effectiveness of PjBL in improving students' critical thinking skills is more optimal when supported by good collaboration skills.

## **DISCUSSION**

The results of this study indicate that the Project Based Learning (PjBL) model has a positive and significant effect on students' critical thinking skills. This finding suggests that PjBL encourages students to actively engage in authentic problem-solving, decision-making, and reflection on project outcomes, which are essential components of critical thinking. By placing students at the center of the learning process, PjBL facilitates the construction of knowledge through meaningful and contextual learning experiences (Almazroui, 2023; L. Zhang & Ma, 2023). Within the framework of the Independent Curriculum, this model is highly relevant because it emphasizes contextual learning and the development of 21st-century competencies, particularly higher-order thinking skills.

Consistent with previous studies, the findings of this research support evidence that PjBL is more effective than conventional instructional approaches in improving students' higher-order thinking skills, especially in vocational and technology-based education contexts (Anggraeni et al., 2023; Jaganathan et al., 2024). The nature of project-based tasks requires students to analyze problems, integrate concepts, and evaluate solutions, thereby promoting deeper cognitive engagement. This confirms that PjBL serves as an effective pedagogical strategy for fostering critical thinking among vocational students who are expected to apply knowledge in real-world situations.

In addition to its impact on critical thinking, the PjBL model was found to have a positive and significant effect on students' collaboration skills. PjBL creates a learning environment that promotes social interaction, effective communication, and teamwork during project completion. Through the division of roles and responsibilities within groups, students are trained to participate actively and take responsibility for collective outcomes (Assaf, 2023; Sarney et al., n.d.). This finding aligns with prior research indicating that sustained social engagement in PjBL significantly enhances students' collaborative competencies (Adl-Amini et al., 2024; Tadesse et al., 2024).

The results also demonstrate that collaboration skills have a positive and significant influence on students' critical thinking abilities. Students who collaborate effectively tend to engage in meaningful discussions, exchange ideas, and evaluate multiple perspectives, which stimulates reflective and analytical thinking processes (Loyens et al., 2023; D. Zhang & Hwang, 2023). Recent studies further confirm that effective collaboration within project-based learning environments contributes to the development of critical thinking and complex problem-solving skills (Khoiri et al., 2023; Thornhill-Miller et al., 2023), highlighting collaboration as a cognitive as well as social enabler of higher-order thinking.

Furthermore, path analysis reveals that collaboration skills function as a partial intervening variable in the relationship between the PjBL model and students' critical thinking skills. This indicates that PjBL not only exerts a direct influence on critical thinking but also enhances this effect indirectly by strengthening collaborative abilities. Collaboration serves as a key mechanism that facilitates in-depth discussion, shared reflection, and collective problem-solving (D. Zhang & Hwang, 2023). These findings are consistent with previous research showing that the integration of PjBL and collaborative learning yields a more optimal impact on critical thinking development than individualistic learning approaches (Thornhill-Miller et al., 2023), positioning PjBL as a comprehensive learning model that operates through both direct and indirect pathways.

## CONCLUSION

The most important finding of this study is that Project Based Learning (PjBL) serves as an effective instructional model for enhancing students' critical thinking skills in vocational education, both directly and indirectly through the strengthening of collaboration skills. This result highlights an essential pedagogical insight: critical thinking development is not solely a cognitive process but is strongly supported by social interaction and collaborative learning experiences. From a scholarly perspective, this study contributes to the existing body of knowledge by empirically confirming the mediating role of collaboration skills in the relationship between PjBL and critical thinking, particularly within the context of vocational education and database learning. By integrating cognitive and social dimensions of learning into a single analytical model, this research extends previous studies that primarily focused on direct instructional effects and reinforces the relevance of PjBL in supporting the goals of the Independent Curriculum and 21st-century competency development.

Despite its contributions, this study has several limitations that should be considered in interpreting the findings and guiding future research. The use of an ex post facto design limits the ability to establish causal relationships with absolute certainty, and the relatively small sample size drawn from a single vocational school may restrict the generalizability of the results. In addition, this study focused only on collaboration skills as an intervening variable, while other potential mediators such as learning motivation, self-regulated learning, or digital literacy were not examined. Therefore, future research is encouraged to employ experimental or mixed-method designs with larger and more diverse samples, as well as to explore additional mediating or moderating variables. Such efforts would provide a more comprehensive understanding of how Project Based Learning influences higher-order thinking skills across different educational contexts.

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