Pro-life
Jurnal Pendidikan Biologi, Biologi, dan Ilmu Serumpun
https://ejournal.uki.ac.id/index.php/prolife

Improving Students' Critical Thinking and Decision-Making Skills through a Problem-Based Learning (PBL) Model Assisted by a Vee Diagram

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Article History

Received: 30 June 2025
Approved: 25 July 2025
Published:27 July 2025

Keywords
critical thinking skills, decision making skills, diagram vee, problem-based learning, biology learning

ABSTRACT

This study is driven by the persistently low levels of students' critical thinking and decision-making skills, despite the implementation of various student-centered learning models such as Problem-Based Learning (PBL). Previous studies have focused mainly on PBL alone, with little attention to visual tools like the Vee diagram, which can enhance understanding and reasoning by helping students organize and reflect on information. However, the effectiveness of integrating the Vee diagram within the PBL framework in improving critical thinking and decision-making skills among high school students remains underexplored, indicating a research gap. This quasi-experimental study aims to evaluate the effectiveness of Vee diagram-assisted PBL compared to conventional PBL in enhancing students' critical thinking and decision-making skills. The study was conducted with 11th-grade science students at SMA Negeri 1 Lebakwangi, Kuningan. Data collection instruments included a critical thinking test (essay format), an observation sheet to assess decision-making skills, and a questionnaire to capture student perceptions of the PBL approach. Data were analyzed using the Independent Samples t-test. The results indicate that students taught using the Vee diagram-assisted PBL model demonstrated significantly greater improvement in critical thinking skills than those taught with conventional PBL. Decision-making skills were also higher in the Vee diagram-assisted PBL group. A positive and significant correlation was found between students' critical thinking and decision-making skills.

INTRODUCTION

Education that aligns with the development of the 21st century relies more on the development of process skills, which include thinking skills, problem-solving skills, and communication skills—all integral to the learning process—to support the optimization of educational outcomes.

21st-century skills that are now the focus of science education researchers include Learning and Innovation Skills and Life and Career Skills (Agustira et al., 2025; Tyas et al., 2023; Nakano & Wechsler, 2018; Alsaleh, 2020). Critical thinking skills are reflective thinking skills that focus on decision-making patterns about what to believe and what to do. Because in decision-making, not only is knowledge and information needed, but one must also be able to think quickly and precisely to produce quality decisions in daily life (Agustira et al., 2025; Pratiwi et al., 2025).

Currently, students' critical thinking and decision-making skills are still low. It is because biology learning is still less effective due to the *teacher-centered* learning methods, which make it difficult for students to understand the lessons delivered by the teacher, as the delivery method still relies on the lecture approach. Student involvement in biology learning activities remains low, resulting in a lack of direct experience through observation or fieldwork that hinders their ability to grasp concepts. Students cannot engage in the process of induced thinking when the teacher asks them to analyze a case provided by the teacher. Likewise, when teachers ask students to provide arguments based on their knowledge, few students do so. This results in concepts that students receive not being the result of their inventions and thoughts, which in turn leads to low thinking skills and learning outcomes among students (Oktavianti & Purnomo, 2024).

There is a close relationship between scientific thinking, specifically critical thinking and decision-making, notably when applying the principles of logic and evidence to define problems, formulate and test hypotheses, and translate the results into action (Agustira et al., 2025). Critical thinking and decision-making skills do not develop on their own in each student; these skills will grow well if they are trained through the learning process. Therefore, teachers must formulate and implement innovative learning models that encourage students to be actively involved in the learning process, develop critical thinking skills, and enhance decision-making skills (Agustira et al., 2025; Jumhur et al., 2024). In principle, critical thinking skills and decision-making skills can be developed, particularly in the Context of Biology learning.

Problem-Based Learning (PBL) is a learning model that is both strategic and important to apply in learning that develops students' critical thinking skills. However, in the implementation of the PBL model in the classroom, it sometimes does not run smoothly as expected. The implementation of the PBL model faces various obstacles, such as limited time to deliver all the material, low readiness and enthusiasm of students for new learning patterns, teachers' difficulties in implementing PBL syntax even though they understand the theory, teachers' tendency to continue using old teacher-centered learning methods, and low student participation due to conventional one-way learning and minimal media (Krismawati et al., 2024),

Based on these obstacles, the culture of our educational society has not been able to fully adapt to the existing situation. It indicates that in Asian countries, including Indonesia, the relationship between teachers and students remains very rigid and formal. Additionally, Asian culture is also intolerant of mistakes, so students may choose to remain inactive in class out of fear of making mistakes (Sanova, 2013). Another obstacle that teachers may face in applying the PBL model is the model itself. Teachers need to understand the concept of PBL in depth, including their role as facilitators and how to manage the learning group effectively (Sriwati, 2021). In biology learning, students often find it challenging to understand the lessons delivered by the teacher because the delivery method still relies on the lecture approach. To improve students' understanding of biological concepts and reduce the occurrence of misconceptions, it is necessary to consider the appropriate form and method of delivery, so that the concepts conveyed by the teacher are easily digested by students (Sapuroh, 2010).

Based on the description above, the learning process is crucial in developing a mindset that fosters a scientific attitude, critical thinking, creativity, independence, and problem-solving abilities. Therefore, learning plans need to be prepared to address these challenges effectively. Careful preparation and organization of learning are the main factors in the success of implementing the PBL model. To overcome these problems, one way to organize an enjoyable problem-solving process is to use Vee Diagrams in the learning process. Vee diagrams with their components will form a specific scheme that has the potential to be applied in PBL (Novak & Gowin, 2006).

The purpose of this research is to improve critical thinking and decision-making skills through the implementation of the Vee Diagram-assisted PBL model. It is important because learning through the PBL model, assisted by the Vee Diagram, can help teachers organize their teaching and learning activities, directing students to develop critical thinking, generate creative ideas, and hone their decision-making skills. Arends emphasizes that problem-based learning, when applied, promotes high-level thinking in problem-oriented situations. Additionally, students participating in problem-based learning engage in learning academic content and problem-solving skills by interacting with real-life situations. In addition, students learn about critical thinking and problem-solving skills, train high-level thinking, including learning how to learn (metacognitive), and train students to become independent learners (Arends, 2012; Savery, 2006).

RESEARCH METHODS

Method

The method used is *a quasi-experimental design* with *Non-Equivalent Pretest and Posttest* Control Groups. The experimental class utilized the PBL Diagram Vee model, while the control class employed the same model to assess the improvement in students' critical thinking and decision-making skills. The research design is presented in **Figure 1.**

Selection of Participants

The subject of the study is a student in Class XI Science at SMA Negeri 1 Lebakwangi, Kuningan Regency. The sampling technique employs *purposive sampling*, specifically experimental and control classes, each comprising a total of 30 students. Sampling is based on average grade values, characteristics, and specific characteristics determined by the researcher.

Data Collection

Data collection utilized test instruments, specifically *a pretest* to assess the initial level of students' critical thinking skills and *a posttest* administered after the learning process. Meanwhile, decision-making uses questionnaires. All instruments, including up to 30 questions on respiratory system material, have undergone the trial stage and are deemed valid and reliable.

Data Analysis

Data analysis was conducted by performing a variable description test to gain an overview of each research variable using the instruments employed. Next, test statistical prerequisites by testing the normality and homogeneity of the data. Moreover, finally, hypothesis testing with the Difference T-Test is used to determine whether two unrelated samples have different mean values. Suppose the significance value (sig. 2-tailed) is greater than 0.05. In that case, it is accepted, meaning that there is no significant difference in average between the experimental class and the control class, while if the significance value (sig. 2-tailed) is less than 0.05, it is rejected, meaning that there is a significant difference in the average between the experimental class and the control class (Trihendradi, 2009).

Group	*Pretest*		*Treatment*		*Posttest*
Experiment (A)	O1	→	X1	→	O2
Control (B)	O1	→	X2	→	O2

Figure 1. Research design

Information:
O1= *Pretest*
O2= *Posttest*
X1= Vee Diagram-assisted PBL learning
X2= PBL Learning without Vee Diagram

Normalized Gain Calculation

The improvement in critical thinking skills that occurs before and after learning in the experimental class and the control class is calculated using the *normalized gain* score, based on the formula provided by Meltzer (2002), as follows.

$$N - \text{gain} = \frac{\text{Skor}_{\text{Posttest}} - \text{Skor}_{\text{Pretest}}}{\text{Skor}_{\text{maximum}} - \text{Skor}_{\text{Pretest}}}$$

The criteria for increasing the normalized gain calculation results were then interpreted using the categories according to Meltzer (2002), namely $g \geq 0.7$ (High), $0.3 \leq g < 0.7$ (Medium), and $g < 0.3$ (Low).

RESULTS AND DISCUSSION

Description of Students' Critical Thinking and Decision-Making Skills

The improvement in students' critical thinking and decision-making skills after applying the PBL model, assisted by the Vee Diagram on respiratory system material, is evident from the results of the posttests carried out, both in the control class and the experimental class. To assess students' critical thinking skills before and after learning the PBL model assisted by the Vee Diagram, data on both pretest scores and posttest are presented in **Tables 1** and **2**, along with gain and N-gain.

Table 1 shows that the average score of *critical* thinking skills gain for students in the control class was 24.17 points lower than that of the experimental class, which was 42.22 points. It was also observed that the average score*/N-gain* value in the control class had a moderate criterion (0.41), whereas the experimental class had an average score/*N-gain* value with high criteria (0.74).

Table 1. Recapitulation of *Pretest*, *Posttest*, *Gain*, and *N-gain* Critical Thinking Skills Scores

Value	Control Class				Experimental Classes			
	Pretest	***Posttest***	***Gain***	***N-gain***	***Pretest***	***Posttest***	***Gain***	***N-gain***
Biggest	52,08	72,92	-	-	58,33	95,83	-	-
Smallest	31,25	56,25	-	-	31,25	77,08	-	-
Average	41,11	65,28	24,17	0,41	43,06	85,28	42,22	0,74

Table 2. Recapitulation of Student Decision-Making Skills Score Control Class and Experimental Class

Indicators	Score/Value of Each Indicator			
	Control Class		Experimental Classes	
	Score	**%**	**Score**	**%**
Declaring a problem	97	80,83	112	93,33
Risk Assessment	94	78,33	105	87,50
Identify (recognize) Options	81	67,50	101	84,17
Information Analysis	77	64,17	100	83,33
Making a decision	76	63,33	100	83,33
Average Score/Total Score	70.83 (Good)		86.33 (Excellent)	

For the average score/*pretest* score, neither the control class nor the experimental class showed a significant difference, indicating that both classes had the same initial skills. It can be seen from the results of the homogeneity test between *the pretest results* of the control class and the experimental class that the significance 0.646 is greater than 0.05. Based on the description above, the implementation of the PBL learning model assisted by the Vee Diagram in this study has been proven to play a role in improving students' critical thinking skills.

Table 2 shows that the control class had an average percentage of scores/scores of decision-making skills with good criteria (70.83%), while the experimental class had an average percentage of scores/scores with very good criteria (86.33%). In addition, the percentage of student decision-making skills for each indicator in the control class and the experimental class with the highest percentage, namely the indicator stating problems, is 80.83% and 93.33%, respectively.

Meanwhile, the lowest percentage for the control class was in the decision-making indicator, at 63.33%, while the experimental class achieved 83.33% in the information analysis and decision-making indicator, respectively. It is because the two samples received different treatments. The control class sample in the learning process employed a pure PBL learning model, whereas the experimental class sample utilized the PBL learning model assisted by the Vee Diagram.

Statistical Prerequisites Test

Normality test. Data normality testing showed that *the pretest*, both in the control class and in the experimental class, the significance value of the initial test data (*pretest*) for the control class was 0.145, and the experimental class was 0.105. Meanwhile, the significance value of the final test data (*posttest*) for the control class was 0.099, and for the experimental class, it was 0.244. Because the significance value of the two classes is greater than 0.05, the data on *the posttest* results of students' critical thinking skills for the two classes are normally distributed. Because the significance value of the two classes is greater than 0.05, it can be concluded that the data from *the students' critical* thinking skills pretest for both classes is normally distributed. The data is presented in **Table 3.**

Homogeneity test. The results of the data homogeneity test had a significance value of 0.646. Since the significance value obtained is greater than 0.05, it can be concluded that the control class and the experimental class have the same or homogeneous variance. Therefore, the test is continued using parametric statistics or hypothesis tests, such as t-tests. The data are presented in **Table 4.**

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Table 3. Normality Test Results of Control Class and Experimental Class

		Kolmogorov-Smirnova			Shapiro-Wilk		
	Class	Statistics	Df	Sig.	Statistics	Df	Sig.
Pretest KBK	Control	.127	30	.200*	.948	30	.145
	Experiment	.161	30	.046	.942	30	.105
Posttest KBK	Control	.133	30	.183	.941	30	.099
	Experiment	.139	30	.145	.956	30	.244

a. Lilliefors Significance Correction

Table 4. Results of the Data Homogeneity Test *for the* Control Class and the Experimental Class

Living Statistic	df1	df2	Sig.
.214	1	58	.646

Hypothesis Test (t-test)

The pretest data analysis results are presented in **Table 5**, showing a significance value of 0.266. Because the probability value is greater than 0.05, the accepted or critical thinking skills of the control class and the experimental class students in the initial test (H_0*pretest*) are not significantly different. The posttest data analysis results are presented in Table 5, showing a significance value of 0.000. Because the probability value is less than 0.05, the null hypothesis is rejected. The critical thinking skills of students who receive treatment with the application of the H_0PBL learning model, assisted by the Vee Diagram, are better than those of students who only receive learning with the PBL model without the Vee Diagram. The application of the PBL learning model, combined with Vee Diagram assistance, suggests an increase in critical thinking skills.

Improvement of Students' Critical Thinking Skills in Control Classes and Experimental Classes

From the results of the gain test analysis (**Table 6**), a significance value of 0.000 was obtained. The significance value was less than 0.05, so it was rejected and accepted, so it can be concluded that there was a significant improvement in students' critical thinking skills in the experimental class after the application of the $H_0 H_1$PBL model assisted by the Vee Diagram compared to the control class that only used the PBL model without the Vee Diagram.

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Table 5. Hypothesis Test Results of KBK Data for Control Class and Experimental Class

		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
Pretest KBK	Equal variances assumed	.214	.646	1.123	58	.266	.933	.831	-.730	2.596
	Equal variances not assumed.			1.123	57.160	.266	.933	.831	-.730	2.597
Posttest KBK	Equal variances assumed	.039	.844	15.481	58	.000	9.600	.620	8.359	10.841
	Equal variances not assumed.			15.481	57.996	.000	9.600	.620	8.359	10.841

Table 6. Improvement of Students' Critical Thinking Skills in Control Classes and Experimental Classes

		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
Gain	Equal variances assumed	4.143	.046	6.550	58	.000	6.300	.962	4.375	8.225
	Equal variances not assumed.			6.550	49.959	.000	6.300	.962	4.368	8.232

Based on the study's results, both classes were given the same level of initial knowledge and skills regarding the human respiratory system. However, after different treatments in the two classes, the experimental class showed higher *posttest* results compared to the control class, with an average score of 85.28 for the experimental class and an average score of 65.28 for the control class. After being treated through the PBL model, assisted by the Vee Diagram in the experimental class, and PBL without the assistance of the Vee Diagram in the control class, the average *posttest* score of the experimental class students was higher than th*at* of the control class students. It can also be seen in the *N-gain value* that the average *N-gain value of the* experimental class, 0.74, according to Meltzer (2002), falls within the high increase criterion, while the average *N-gain* value of the control class is 0.41, which falls within the medium increase criterion. The data on students' critical thinking skills were collected after the learning process was completed, in both the experimental class that used the PBL model with the Vee Diagram and the control class that used the PBL model without the Vee Diagram. In measuring students' critical thinking skills assisted by the Vee Diagram, the assessment is conducted both before and after the learning process using a critical thinking skills instrument consisting of 12 descriptive questions, whose preparation is based on critical thinking indicators.

The results of implementing PBL have shown a non-significant increase in critical thinking and decision-making skills. However, the application of the Vee Diagram in the learning process using the PBL model further improves students' thinking skills compared to the control class that only uses the PBL model. Students' critical thinking skills were observed to have shown significant improvement compared to learning that only used the PBL model without the Vee Diagram. Research by Husen et al. (2017) also demonstrates that the PBL model can enhance critical thinking skills. The visualization of the improvement in students' critical thinking skills for each indicator in both the control class and the experimental class is shown in **Figure 2.**

The results of students' critical thinking skills for the indicators in further clarification have an *N-gain* score, which indicates the highest category compared to other indicators, at 0.88. It is evidenced by the scores obtained on the critical thinking skills instrument. It means that students can define terms, consider their definitions, and identify underlying assumptions. However, some students have been unable to write down descriptions of the indicators to provide further explanations. It is estimated that many students still do not read source books that align with the material being discussed or do not seek additional relevant information.

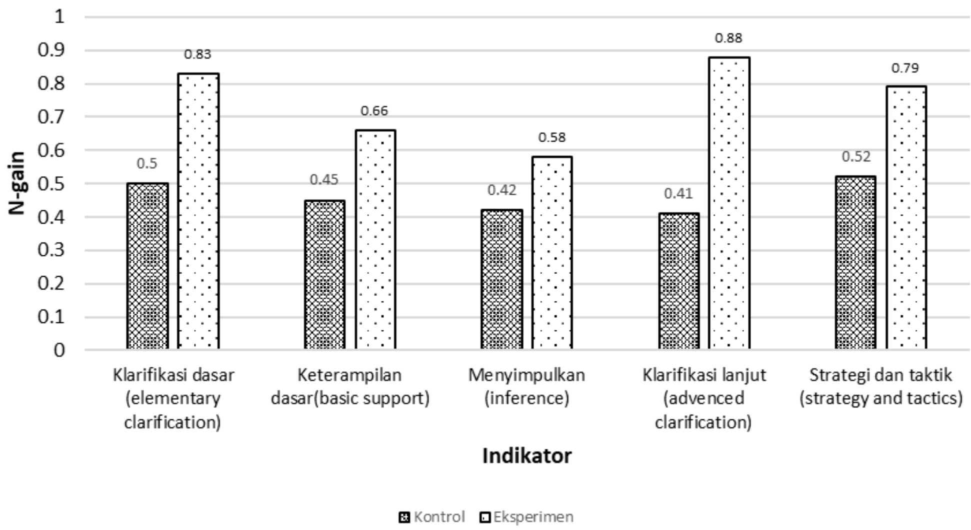

Figure 2. N-gain score chart of students' critical thinking skills: each control class indicator and experimental class

Seifert and Hoffinung (1994) state that practical critical thinking requires the student to observe when they are making a serious effort to understand an idea and consciously recognize when they need new information, and to predict how they can easily collect and analyze the information obtained. One of the characteristics of critical thinking is the ability to use existing information as a basis for formulating solutions or making decisions. Type PBL can provide students with broad opportunities to develop critical thinking skills, propose creative ideas, and communicate them to their friends (Darwati & Purana, 2021; Handayani & Koeswanti, 2021).

The improvement of students' critical thinking skills in the experimental class was higher compared to the control class. The Vee Diagram used in the application of the PBL model has great potential to organize problem-based learning, as it not only helps build high-level skills in solving problems but also trains students to develop and improve their conceptual and methodological understanding, as well as their critical thinking and reasoning abilities (Stuart & Scott, 2009).

Gowin (1981) stated that the Vee diagram is a metacognition-based learning strategy that aims to facilitate students' understanding of the relationship between conceptual and procedural knowledge. In the context of practicum, Vee diagrams can be used to design and reflect on practicum activities comprehensively. Students not only carry out the procedures technically, but also understand the conceptual meaning of the activities they are performing. Thus, Vee diagrams serve as a bridge between theoretical knowledge and practical experience, thus allowing students to integrate the two in the process of scientific thinking. This Vee diagram also encourages students to think reflectively and critically about the relationship between theory and direct experience.

Flavell (1979) notes that Vee's diagram helps students realize their thinking process, as well as increase awareness of what is being learned and how the learning process takes place. In other words, Vee diagrams are not only procedural but also play a crucial role in designing meaningful practicum activities. By connecting theory and practice, this diagram facilitates the development of critical thinking skills through concept analysis, data evaluation, and reflection on the results of the practicum.

Students' Decision-Making Skills in the Problem-Based Learning (PBL) Learning Process Assisted by Vee Diagrams

Critical thinking skills have a significant impact on a person's cognitive abilities. If students have high cognitive skills, then their thinking skills are likely to be high as well. Srimadevi, T., & Saraladevi, D.K. (2016) state that the decision-making process is influenced by a person's cognitive and emotional level. Furthermore, Harasym, P.H., Tsai, T.C., & Munshi, F.M. (2013) state that decision-making is a complex process involving the interaction of knowledge, skills, and attitudes. Based on the study's results, it is evident that students in Class XI-IPA at SMAN 1 Lebakwangi who possess high critical thinking skills also exhibit good decision-making skills.

Students' decision-making skills are compatible with critical thinking skills. The decision-making skills of students are developed in the experimental class in the PBL model learning process. The Vee diagram differs significantly from the control class, whose learning only utilizes the PBL model. The results show that of the five indicators of student decision-making skills, most of them are on good criteria: identifying or recognizing criteria, evaluating alternatives based on criteria, and making decisions. In decision-making, students are excellent at stating problems and formulating a list of alternatives to support their choices. However, students are still relatively lacking in identifying options based on existing criteria, so the decisions taken are still not accurate.

The relatively low decision-making skills of students in the indicator of identifying based on criteria are because students are rarely faced with complex problems or problems that require deep thinking. Students are only able to face or work on problems that require only a certain level of precision. It aligns with Suryabrata's (2004) statement, which notes that decision-making can be related to reasoning tasks carried out by a person during the learning process.

Correlation of Critical Thinking Skills and Student Decision Making

The relationship between critical thinking skills and decision-making in experimental class students has a strong and significant correlation between critical thinking skills and student decision-making skills. It means that the greater the average score of critical thinking skills obtained by students, the more decision-making skills will increase. Wade explained that critical thinking skills involve the ability to ask various questions, identify problems, examine facts, analyze assumptions and biases that arise, avoid emotional reasoning, avoid oversimplification, consider alternative interpretations, and tolerate ambiguity. It is beneficial in decision-making skills, as Silverman & Smith argue that critical thinking requires a person to dive into the questions "What knowledge exists?", "How do I solve problems?" (Philosophy, 2008)

In line with the research results of Tanglang, N., & Ibrahim, A.K. (2016), which show a relationship between academic achievement and decision-making skills. It means that the decision-making process requires critical and analytical thinking that can be improved in practice, so that it can be concluded that decision-making is an effort to achieve goals by using systematic stages to choose the right alternative. *"Decision making a higher-order thinking skills that give students the ability to think clearly in diverse situations."* From the definition mentioned above, decision-making is a follow-up to problem-solving and is an integral part of critical thinking skills. It means that the decision-making process requires critical thinking and analysis, as it involves achieving the final goal through a systematic process of choosing alternatives. It is also supported by the opinion of Suryabrata (2004), who reveals that the thought process begins with the formation of understanding, the development of opinions, and the drawing of conclusions or decision-making.

The relationship between critical thinking and decision-making lies in the fact that critical thinking is a component of high-level thinking. Every individual uses high-level thinking to solve problems, whose ultimate goal is decision-making. It aligns with Ennis's (1996) assertion that critical thinking is a process aimed at making rational decisions about what to believe.

This study has limited subject-related limitations, focusing only on the use of PBL with Vee Diagrams without considering external variables such as learning motivation, initial skills, or the role of teachers. In the future, it will be necessary to conduct further research to obtain a more representative picture involving multiple schools or diverse student backgrounds, as well as the development of measurement instruments, such as analytical rubrics or performance tests. It is also necessary to consider other variables, such as students' learning styles, perceptions of learning methods, and factors related to the learning environment.

CONCLUSION

The improvement of students' critical thinking and decision-making skills through the PBL model of the Vee Diagram on the material of the human respiratory system in the experimental class and the PBL model without the Vee Diagram on the material of the human respiratory system in the control class, it can be concluded that the improvement of students' critical thinking skills between the control class and the experimental class obtained different results. Although the control class achieved an *average N-gain* score of 0.41, categorized as moderate, the improvement was not statistically significant. Meanwhile, the experimental class had an average *N-gain* score of 0.74, meeting very high criteria, and experienced a significant increase in performance. The students' decision-making skills in the control class had an average percentage of 70.83%, meeting good criteria, while the experimental class had an average percentage of 86.33%, meeting excellent criteria. It indicates a difference in students' decision-making skills between the control class and the experimental class. Thus, there is a relationship between critical thinking skills and students' decision-making skills. It means that if students possess high critical thinking skills, their decision-making skills are likely to be equally high.

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