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Effect of the Problem-Based Learning Model On Students' Critical Thinking Skills in Human Digestive Learning

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Abstract: This study was motivated by the low level of students' critical thinking skills in science learning, particularly in the human digestive system topic, where teacher-centered instruction often encourages memorization rather than conceptual understanding and problem-solving. Therefore, this study aimed to examine the effect of the Problem-Based Learning (PBL) model on students' critical thinking skills. This research employed a quasi-experimental design with a nonequivalent control group, involving 60 eighth-grade students: 30 in the experimental class and 30 in the control class. The experimental class received instruction using the PBL model, while the control class was taught through conventional learning. Data were collected using essay tests based on Ennis' critical thinking indicators and observation sheets, then analyzed using normality, homogeneity, and independent-samples t-tests in SPSS version 27. The novelty of this study lies in integrating Ennis' critical thinking indicators with both test and observation instruments to evaluate the effectiveness of PBL in science learning. The results showed that the experimental class achieved a higher mean posttest score (81.17) than the control class (64.83). Observation results also indicated better critical-thinking performance in the experimental class (87) than in the control class (75). The independent-samples t-test yielded a Sig. (2-tailed) value of < 0.05, indicating that the PBL model had a significant effect on students' critical thinking skills. These findings demonstrate that PBL is effective in enhancing students' critical thinking skills and supports its implementation in science learning to promote 21st-century competencies.

Keywords: Critical Thinking Skills; Human Digestive System; Problem-Based Learning.

Introduction

The demands of 21st-century education require students not only to master knowledge but also to develop skills that support their success in responding to the rapid advancement of science and technology. One essential competency to develop is critical thinking, which is included among the 4C competencies (critical thinking, communication, collaboration, and creativity) [1]. Critical thinking skills play an important role in helping students analyze information, evaluate problems, draw conclusions, and make logical decisions. In science learning, these skills are particularly important because science education is not only oriented toward concept mastery but also emphasizes scientific processes through observation, investigation, and problem-solving activities [2].

Critical thinking skills in science learning can be identified using the indicators proposed by Robert H. Ennis [3], which comprise five main aspects: elementary clarification, basic support, making inferences, advanced clarification, and determining strategies and tactics. These indicators are widely used in educational research as a basis for developing assessment instruments as well as a framework for improving students' critical thinking abilities. In science education, strengthening critical thinking indicators plays a significant role in helping students gain a more comprehensive understanding of the learning materials, evaluate the accuracy of information, and appropriately formulate scientific conclusions [4]. In addition to cognitive aspects, critical thinking reflects mental attitudes such as openness to diverse perspectives and a strong commitment to seeking the truth through logical reasoning. Therefore, critical thinking skills are considered an essential component of science learning because they are closely associated with reasoning and problem-solving abilities [4]. However, in practice, classroom instruction still frequently relies on conventional approaches that position teachers as the primary source of information, making students passive and limiting their opportunities to develop higher-order thinking skills [5]. As a result, students become more accustomed to memorizing learning materials rather than understanding concepts deeply.

The low level of students' critical thinking skills in Indonesia is reflected in the results of the 2022 Programme for International Student Assessment (PISA). Indonesia ranked 68th among 81 participating countries, obtaining a science score of 383, which remains considerably below the OECD average score of 485 [6]. These findings indicate that Indonesian students still experience difficulties in analyzing information, evaluating evidence, and solving scientific problems. Similarly, Lutfiah et al. [7] reported that students' critical thinking skills remain low because classroom learning often provides limited opportunities for active inquiry and analytical thinking. Teacher-dominated

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instruction further reduces students' engagement in meaningful discussion and reasoning activities [5].

A similar situation was identified at SMP Negeri 35 Medan based on preliminary classroom observations and interviews with eighth-grade science teachers. The findings revealed that students' critical thinking skills remained relatively low, particularly when learning about the human digestive system. This condition was confirmed by the results of a preliminary critical thinking test, which showed an average score of 44.22, categorized as less critical. Students experienced difficulties in identifying problems, organizing relevant information, analyzing relationships among concepts, and drawing logical conclusions. Teachers also reported that the human digestive system is one of the most challenging science topics because it involves abstract biological processes that cannot be directly observed [8]. Moreover, the topic requires students to understand the interrelationships among nutrients, digestive organs, digestive processes, and digestive disorders. As a result, many students tend to memorize digestive organs and their functions without fully understanding the mechanisms underlying the digestive process, making it difficult for them to answer analytical and higher-order thinking questions [9].

These findings indicate the need for an instructional approach that actively engages students in analyzing problems, discussing ideas, and constructing knowledge independently. One instructional model that aligns with these objectives is PBL. PBL emphasizes authentic problems as the starting point for learning, encouraging students to investigate problems collaboratively, develop solutions based on scientific reasoning, and communicate their findings. Within this model, students become active participants in the learning process, while teachers act as facilitators, guiding inquiry and reflection [10].

The implementation of the PBL model plays an important role in developing various student skills. This learning model not only enhances students' critical thinking abilities but also fosters positive characteristics such as discipline, responsibility, tolerance, and the ability to collaborate effectively in teams. In addition, implementing PBL can increase students' motivation to learn and encourage their active participation throughout the learning process [11]. Several studies have demonstrated the effectiveness of PBL in improving students' thinking skills. Humaira et al. [12] reported that the continuous implementation of PBL positively enhances students' critical thinking skills. In science learning, Handayani et al. [13] stated that PBL not only supports the development of critical thinking skills but also helps students gain a more comprehensive understanding of science concepts. This occurs because students are actively involved throughout the learning process, beginning with formulating questions, analyzing problems, and ultimately generating solutions.

Although previous studies consistently support the effectiveness of PBL, several research gaps remain. Most studies have primarily measured students' critical thinking using cognitive achievement tests, while limited attention has been given to observing students' critical thinking performance throughout the learning process. In addition, many previous studies have investigated PBL in general science learning contexts without specifically focusing on the human digestive system, a topic characterized by abstract concepts and complex relationships among biological processes. Consequently, empirical evidence regarding the effectiveness of PBL in developing students' critical thinking skills in this topic remains limited.

To address these gaps, the present study evaluates students' critical thinking skills using both essay tests and classroom observation sheets developed based on Ennis' critical thinking indicators. Unlike previous studies that relied mainly on cognitive test results, this study combines cognitive and observational assessments to provide a more comprehensive evaluation of students' development of critical thinking during learning. Therefore, this study contributes to the existing literature by providing empirical evidence on the effectiveness of PBL in improving critical thinking skills in science learning, particularly in the human digestive system topic.

Based on the identified research gaps, this study aimed to examine the effect of the Problem-Based Learning model on students' critical thinking skills in learning the human digestive system. The findings are expected to enrich the existing literature by providing empirical evidence on the effectiveness of PBL assessed through both cognitive outcomes and classroom observations, while also offering practical implications for improving science learning and fostering students' critical thinking skills.

Research Methods

Research Type and Design

This study employed a quasi-experimental design with a nonequivalent control group to examine the effect of the PBL model on students' critical thinking skills in learning about the human digestive system. This design was selected because random assignment of participants was not feasible within the existing classroom setting. The study involved two intact classes: an experimental group and a control group. Before the intervention, both groups completed a pretest to assess their initial critical-thinking skills. Subsequently, the experimental group received instruction using the PBL model, whereas the control group was taught using conventional teacher-centered instruction. At the end of the intervention, both groups completed a posttest to assess differences in students' critical thinking skills following the different instructional treatments.

Research Setting and Participants

This study was conducted at SMP Negeri 35 Medan, located in Medan, North Sumatra, Indonesia, during the second semester of the 2025/2026 academic year, from February to March 2026.

The population consisted of all eighth-grade students of SMP Negeri 35 Medan, comprising 11 classes with a total of 343 students. The sample was selected using purposive sampling based on criteria relevant to the study's objectives. The research sample consisted of 60 students from two classes. Class VIII-6, consisting of 30 students, served as the experimental group and received instruction using the Problem-Based Learning model, whereas Class VIII-3, consisting of 30 students, served as the control group and received conventional instruction. Before the treatment was implemented, both groups completed a pretest to assess their initial critical-thinking skills.

Data Collection Techniques

Data were collected using both test and non-test techniques. The test technique consisted of essay tests administered as pretests and posttests to measure students' critical-thinking skills on the human digestive system. The pretest was administered before the instructional treatment to determine students' initial abilities, while the posttest was conducted after the intervention to evaluate students' critical thinking skills following the learning process. The non-test technique consisted of classroom observations conducted throughout the learning process. The observation sheet was developed based on Ennis' critical thinking indicators, namely elementary clarification, basic support, inference, advanced clarification, and strategies and tactics. The observations were intended to assess students' critical thinking performance during discussions, investigations, presentations, and classroom interactions.

Research Instruments

This study employed two research instruments: an essay test and a classroom observation sheet. The essay test consisted of ten questions developed based on Ennis' critical thinking indicators: elementary clarification, basic support, inference, advanced clarification, and strategies and tactics**.** The essay questions covered higher-order cognitive levels, namely C4 (analyzing), C5 (evaluating), and C6 (creating), based on the revised Bloom's Taxonomy. The classroom observation sheet was also developed using the same indicators to assess students' critical thinking skills throughout the learning process.

Prior to their implementation, both instruments were validated by experts to ensure their content validity. The results of the validity test indicated that all test items met the validity criteria. Furthermore, the reliability test demonstrated that the instruments were highly reliable, indicating they were appropriate for measuring students' critical thinking skills. The classroom observation sheet was also reviewed and validated by science education experts before its implementation to ensure its suitability as an instrument for observing students' critical thinking skills during classroom learning.

Research Procedure

The study was conducted over three instructional meetings, with each meeting lasting 2 × 45 minutes. Before the intervention, both the experimental and control groups completed a pretest to assess students' initial critical thinking skills. The experimental group was taught using the PBL model. During the first meeting, students studied the topic of nutritional functions in food by engaging with an authentic problem presented through a video. They then worked collaboratively using student worksheets (LKPD) to gather information, analyze the problem, present their findings, and evaluate the proposed solutions. The second meeting focused on the human digestive system, where students investigated a contextual problem related to unhealthy eating habits. In the third meeting, students studied digestive system disorders and their prevention by analyzing authentic case scenarios. Throughout the three meetings, the implementation of the PBL model followed five instructional stages: (1) orienting students to the problem, (2) organizing students for learning, (3) guiding individual and group investigations, (4) developing and presenting solutions, and (5) analyzing and evaluating the problem-solving process. Students' critical thinking skills were continuously assessed using classroom observation sheets based on Ennis' critical thinking indicators.

Meanwhile, the control group studied the same learning materials over the same period using conventional teacher-centered instruction, consisting of lectures, question-and-answer sessions, and individual exercises without implementing the structured stages of the PBL model. After the instructional intervention, both groups took a posttest to evaluate students' critical thinking skills following the different learning treatments.

Data Analysis

The collected data were analyzed using IBM SPSS Statistics version 27. Data normality was examined using the Kolmogorov-Smirnov test, while homogeneity of variance was assessed using Levene's test. The data were considered normally distributed and homogeneous when the significance value (Sig.) was greater than 0.05. The research hypothesis was tested using an independent-samples t-test after the assumptions of normality and homogeneity were satisfied. If these assumptions were not met, the Mann-Whitney U test was employed as a non-parametric alternative. The decision criteria were as follows: if the significance value (Sig.) was less than 0.05, the null hypothesis (H_0) was rejected and the alternative hypothesis (H_a) was accepted; otherwise, H_0 was accepted. The observation data were analyzed descriptively using Microsoft Excel by calculating the mean score for each critical thinking indicator to describe the development of students' critical thinking skills throughout the learning process.

Ethical Considerations

Prior to data collection, permission to conduct the research was obtained from the principal of SMP Negeri 35 Medan. The science teacher and participating students were informed about the study's objectives and procedures before the study's implementation. Participation was voluntary, and all data collected were used solely for research purposes. The identities of all participants were kept confidential, and the research findings were reported anonymously to protect participants' privacy.

Results and Discussion

Students' Critical Thinking Skills Test Results

This section presents students' critical thinking skills based on the pretest and posttest results. The assessment employed an essay test consisting of ten questions developed according to Ennis' five critical thinking indicators: elementary clarification, basic support, inference, advanced clarification, and strategies and tactics. The test was administered before and after the learning intervention to compare students' initial and final critical thinking skills in both the experimental and control groups.

Table 1. Mean Scores of Pretest and Posttest in the Experimental and Control Groups.

Class	Pretest Mean	Posttest Mean	N
Experimental	38.00	81.17	30
Control	35.58	64.83	30

As presented in Table 1, both groups demonstrated improvements in critical thinking skills after the instructional intervention. The experimental group's mean score increased from 38.00 in the pretest to 81.17 in the posttest, while the control group's mean score increased from 35.58 to 64.83. These results indicate that students who received instruction through the Problem-Based Learning (PBL) model achieved higher critical thinking scores than those who received conventional instruction.

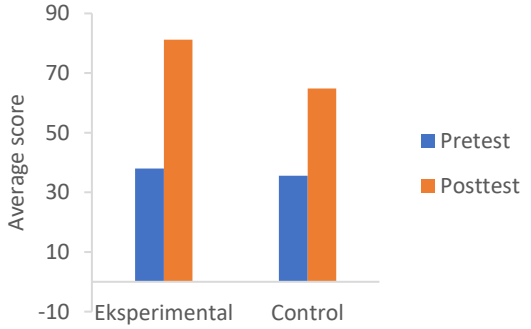


Figure 1. Comparison of Pretest and Posttest Scores in Experimental and Control Classes

Figure 1 compares the average pretest and posttest scores of the experimental and control classes. Both classes showed improvement in students' critical thinking skills after the learning process, but the experimental class achieved a higher increase, from 38 to 81.17, while the control class increased from 35.58 to 64.83. These results indicate that the learning model used in the experimental class was more effective in improving students' critical thinking skills.

Normality Test

Normality testing was conducted as an initial requirement to ensure that the data were normally distributed. Since each class had 30 students ($n < 50$), the Shapiro–Wilk test was performed in SPSS version 27.0.1. The conclusion was based on the significance value (Sig.), where the data are considered normally distributed if Sig. > 0.05, and not normally distributed if Sig. < 0.05. The results of the normality test for the pretest and posttest are presented in Table 2.

Table 2. Results of Normality Test

Class	Evaluation	(Sig.)	Conclusion
Experimental	Pretest	0.24	Normal
	Posttest	0.10	Normal
Control	Pretest	0.59	Normal
	Posttest	0.44	Normal

The normality test results show that the significance values for the pretest and posttest in the experimental class are 0.24 and 0.10, respectively. These values exceed the 0.05 criterion, indicating that the data distribution in the experimental class meets the assumption of normality. In the control class, the significance values for the pretest and posttest are 0.59 and 0.44, respectively, both of which are also above the 0.05 threshold. Thus, all data from both classes are normally distributed.

Homogeneity Test

Homogeneity testing was conducted to ensure that the variances of the experimental and control groups were equal (homogeneous). The test was performed using Levene's test with SPSS version 27.0.1. Data are considered homogeneous if the significance value (Sig.) is greater than 0.05, and not homogeneous if Sig. is less than 0.05. The results of the homogeneity test are presented in Table 3.

Table 3. Results of Homogeneity Test

Test Type	Sig. Based on Mean	Sig. Value Criterion α (0.05)	Conclusion Sig. >α (0.05)
Pretest of the experimental class and the control class	0.862	0.05	Homogeneous
Posttest of the experimental class and the control class	0.413	0.05	Homogeneous

The results indicated that the significance value was greater than 0.05, which means that the variances of the experimental and control classes were homogeneous.

Hypothesis Testing

Hypothesis testing in this study was conducted using an independent-samples t-test with a two-tailed test in SPSS version 27.0.1, as the data met all the prerequisite assumptions. This test was used to examine the effect of the PBL model on students' critical thinking skills. Conclusions were based on the Sig. (2-tailed) value with a significance level of $\alpha = 0.05$ (95% confidence level), where Sig. < 0.05 indicates that H_0 is rejected and H_a is accepted, while Sig. > 0.05 indicates that H_0 is accepted and H_a is rejected. The test results are presented in Table 4.

Table 4. Results of Hypothesis Test (Independent Sample T-Test)

Class	N	Mean	Std. Dev.	Sig. (2-tailed)	Conclusion
Experimental	30	81.17	10.35	< 0.001	H_a accepted
Control	30	64.83	12.01		

The independent-samples t-test results show that the significance value (Sig. 2-tailed) is less than 0.05. The significant difference between the two groups demonstrates that the PBL model positively affected students' critical thinking skills when learning about the human digestive system. The higher posttest achievement in the experimental group can be explained by PBL's characteristics, which position students as active learners who construct their understanding through authentic problem-solving activities.

Throughout the learning process, students were encouraged to identify problems, investigate relevant information, evaluate evidence, formulate explanations, and determine appropriate solutions. These activities provided opportunities to practice higher-order thinking skills rather than merely recall previously learned information [14].

This finding is consistent with Lukitasari et al. [15], who reported that learning environments that encourage questioning, discussion, argumentation, and evaluation of information are effective in developing students' critical thinking skills. Similarly, Ekandari et al. [16] reported that PBL encourages students to participate actively in knowledge construction, while Nurhayati et al. [17] emphasized its contribution to students' intellectual development. These findings can also be understood through constructivist learning theory, which explains that meaningful learning occurs when students actively construct knowledge through interaction with problems and learning experiences rather than passively receiving information from teachers [18].

The implementation of problem-based student worksheets (LKPD) also supported students throughout the learning process. The worksheets guided students in identifying problems, collecting relevant information, evaluating evidence, and formulating logical explanations based on scientific reasoning. In this context, the LKPD served as instructional support, helping students engage in systematic inquiry and gradually develop independent thinking. This finding is consistent with Marhaeni et al. [19], who demonstrated that PBL-based worksheets provide structured opportunities for analysis, discussion, and problem-solving.

Critical Thinking Skills Based on Each Indicator

To obtain a more detailed understanding of students' critical-thinking achievement, an analysis was conducted using Ennis' five indicators. This analysis aimed to identify differences in students' performance between the experimental and control groups after the instructional intervention. The comparison of achievement for each indicator is presented in Figure 2.

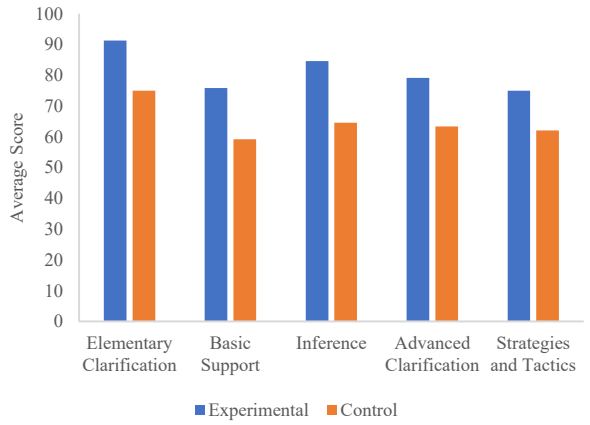


Figure 2. Comparison of Critical Thinking Skills Based on Each Indicator

Figure 2 shows that the experimental group achieved higher scores than the control group across all five critical thinking indicators. In both groups, elementary clarification obtained the highest achievement. Meanwhile, the lowest achievement was found in strategies and tactics in the experimental group and basic support in the control group. These findings indicate that PBL provided more favourable learning conditions for the development of different dimensions of students' critical thinking skills.

The high achievement in elementary clarification can be explained by PBL's problem-orientation stage. During this stage, students were presented with contextual problems related to nutritional imbalance and digestive disorders. They were encouraged to identify the main problems, recognize relevant information, and formulate preliminary explanations before proceeding to further investigation. These activities strengthened students' ability to understand and clarify problems, which represents a fundamental component of critical thinking [20].

The organization stage further supported the development of basic support. Through problem-based worksheets, students identified information that was already available and information that required further investigation. They also used relevant learning resources to support their arguments. These activities encouraged students to consider the relevance and credibility of information before using it as evidence to explain scientific problems [21]. Nevertheless, some students still had difficulty selecting the most appropriate supporting evidence, indicating that critical evaluation requires continuous practice. This finding is consistent with Soleha and Azizah [22], who emphasized the importance of evaluating information credibility before making scientific judgments.

The inference indicator also demonstrated substantial improvement in the experimental group. During the investigation stage, students collected information from textbooks, discussions, and other learning resources. They then analyzed relationships among concepts and formulated conclusions based on the available evidence. These activities required students to interpret information and construct logical explanations rather than simply recall memorized facts [23]. This finding supports Hoar et al. [24], who explained that inference plays an important role in developing students' reasoning abilities because learners must interpret evidence before reaching scientifically justified conclusions.

The advanced clarification indicator improved through activities that required students to explain concepts, defend their reasoning, and respond to questions during presentations. Students were encouraged to communicate their explanations and justify their conclusions using logical arguments. However, some students still relied on intuitive reasoning when responding to more challenging questions. This indicates that developing deeper conceptual explanations requires repeated opportunities for scientific argumentation. This finding is consistent with Putri and Prahani [25], who reported that presentation and discussion activities in PBL can strengthen students' conceptual understanding and analytical reasoning.

Among the five indicators, strategies and tactics obtained the lowest achievement in the experimental group, although improvement was still observed. This indicator requires students to evaluate alternative solutions, determine appropriate strategies, justify decisions using scientific evidence, and consider the effectiveness of their chosen solutions [26]. These processes involve more complex

cognitive and metacognitive abilities, including planning, monitoring, and evaluating one's own reasoning. Therefore, the relatively lower achievement of this indicator suggests that strategic thinking requires longer learning experiences and continuous opportunities for reflection. Similar findings were reported by Aprina et al. [27], who emphasized that developing systematic decision-making strategies requires intensive instructional support.

Overall, the differences across the five indicators demonstrate that critical thinking does not develop uniformly. Some indicators, particularly elementary clarification and inference, may improve more rapidly because they are directly practiced during problem identification and investigation. In contrast, strategies and tactics require more complex reasoning and therefore may develop progressively through sustained learning experiences.

Observation Results of Students' Critical Thinking Skills

In addition to the essay test, classroom observations were conducted over three meetings to examine students' critical thinking performance during the learning process. The observation instrument was developed based on Ennis' five indicators: elementary clarification, basic support, inference, advanced clarification, and strategies and tactics. The assessment focused on students' observable behaviours, including asking questions, expressing opinions, analyzing information, and responding to problems presented during classroom activities.

Problem Based Learning Class

The observation results showed that students' critical-thinking performance in the PBL class improved progressively over the three meetings. As shown in Table 5, the mean observation score increased from 45.17 in the first meeting to 67.00 in the second and reached 87.00 in the third.

Table 5. Results of Critical Thinking Skills Observation of Students in the PBL Class

Critical Thinking Criteria	Meeting I	Meeting II	Meeting III
Elementary Clarification	50.83 (Less Critical)	69.17 (Fairly Critical)	93.33 (Very Critical)
Basic Support	45.83 (Less Critical)	65.00 (Fairly Critical)	86.67 (Very Critical)
Inference	46.67 (Less Critical)	68.33 (Fairly Critical)	84.17 (Very Critical)
Advanced Clarification	40.00 (Not Critical)	63.33 (Fairly Critical)	81.67 (Very Critical)
Strategies and Tactics	42.50 (Not Critical)	69.17 (Fairly Critical)	89.17 (Very Critical)
Mean Score	45.17 (Less Critical)	67.00 (Fairly Critical)	87.00 (Very Critical)

The improvement in observation scores indicates that students increasingly demonstrated critical-thinking behaviours during the learning process. Students became more capable of identifying problems, analyzing relevant information, presenting arguments, and evaluating proposed solutions. These developments can be associated with the five stages of PBL, which provided repeated opportunities for students to engage in problem identification, information gathering, investigation, presentation, and evaluation.

The progressive improvement also indicates that critical thinking developed not only as a cognitive outcome measured through the posttest but also as a process reflected in students' actions and responses during learning. Through continuous engagement in investigation, discussion, and reflection, students had opportunities to reorganize their existing understanding and integrate newly acquired scientific concepts. This interpretation is consistent with constructivist learning theory, which emphasizes the active construction of knowledge through meaningful learning experiences [18].

Conventional Class

Students in the conventional class also demonstrated improvements in critical thinking performance across the three meetings, although the increase was lower than that observed in the PBL class. The observation results are presented in Table 6.

Table 6. Results of Critical Thinking Skills Observation of Students in the Conventional Class

Critical Thinking Criteria	Meeting I	Meeting II	Meeting III
Elementary Clarification	45.00 (Less Critical)	64.00 (Fairly Critical)	88.33 (Very Critical)
Basic Support	34.17 (Not Critical)	53.00 (Less Critical)	73.00 (Critical)
Inference	35.00 (Not Critical)	55.83 (Fairly Critical)	72.50 (Critical)
Advanced Clarification	26.67 (Not Critical)	51.67 (Less Critical)	70.00 (Fairly Critical)
Strategies and Tactics	29.17 (Not Critical)	46.67 (Less Critical)	70.83 (Fairly Critical)
Mean Score	34.00 (Not Critical)	54.33 (Less Critical)	75.00 (Critical)

The mean observation score in the conventional class increased from 34.00 in the first meeting to 54.33 in the second and reached 75.00 in the third. Although these results indicate that students' critical-thinking performance improved during the learning process, overall achievement remained lower than that of the experimental group.

This difference can be related to the characteristics of conventional instruction, which predominantly relies on teacher explanations, question-and-answer sessions, and

individual exercises. Although these activities provide opportunities for students to acquire and practice subject knowledge, they offer relatively fewer opportunities for independent investigation and systematic problem-solving. Consequently, students may become more accustomed to receiving and remembering information than actively evaluating evidence and constructing their own explanations [28].

These findings are consistent with Ghufron et al. [29], who reported that teacher-dominated instruction tends to encourage memorization rather than meaningful conceptual understanding and critical analysis. Similarly, Aisyah et al. [30] explained that instructional approaches emphasizing content delivery may provide insufficient opportunities for students to develop higher-order thinking skills through investigation and problem-solving.

The comparison between the two groups further supports the quantitative findings. The experimental group achieved a mean observation score of 87.00 in the third meeting, whereas the control group achieved 75.00. This difference indicates that students in the PBL class demonstrated stronger critical thinking performance during classroom learning than students in the conventional class.

The higher achievement in the PBL class can be attributed to the use of contextual problems related to the human digestive system, including unhealthy eating habits and digestive disorders. These problems encouraged students to connect scientific concepts with situations encountered in everyday life. Through investigation and discussion, students were given opportunities to analyze information, consider alternative explanations, and formulate solutions based on scientific reasoning [31]. This is consistent with Suriaman et al. [32], who emphasized the importance of problem-solving and reflective thinking in developing critical thinking skills.

The observation findings also provide additional evidence of the relationship between students' learning processes and their cognitive achievement. The higher posttest scores in the experimental group were accompanied by improvements in observable critical-thinking behaviours across the three meetings. This consistency suggests that the development of critical thinking was reflected not only in students' final test results but also in how they responded to problems, analyzed information, and formulated conclusions during learning.

Overall, the findings demonstrate that PBL's effectiveness was supported by the integration of authentic problems, structured investigations, problem-based worksheets, and opportunities for students to explain and evaluate their reasoning. Compared with conventional instruction, PBL provided more opportunities for students to practice critical thinking through meaningful learning activities. These findings further support previous research indicating that PBL is an effective instructional approach for developing students' critical thinking skills [33]. Moreover, the integration of essay tests and classroom observations provides a more comprehensive description of students' development of critical thinking by examining both cognitive outcomes and observable learning behaviours.

Despite these positive findings, several limitations should be considered. This study involved only 60 eighth-grade students from one junior high school and focused exclusively on the human digestive system. In addition, the instructional intervention was conducted over only three meetings. Therefore, the findings should be interpreted within the context of the study and should not be generalized to all educational settings. Future research should involve larger and more diverse samples, implement PBL over longer instructional periods, and examine its effectiveness across different science topics and educational contexts.

Conclusion

This study demonstrates that implementing the Problem-Based Learning (PBL) model effectively improves eighth-grade students' critical thinking skills in learning about the human digestive system at SMP Negeri 35 Medan. Beyond improving cognitive achievement, PBL also promoted greater student engagement throughout the learning process by encouraging active participation in problem identification, collaborative investigation, scientific discussion, argumentation, and evidence-based decision-making. These findings indicate that critical thinking develops not only as a learning outcome but also as a continuous process fostered through meaningful inquiry-oriented learning experiences. The findings contribute theoretically by providing further empirical evidence that critical thinking develops progressively across different cognitive dimensions when students actively construct knowledge through authentic problem-solving. The integration of cognitive assessment and classroom observation also offers a more comprehensive understanding of students' development of critical thinking by demonstrating consistency between learning outcomes and learning behaviours. In practice, these findings suggest that PBL can be an effective instructional approach in biology and science education by creating student-centred learning environments that strengthen conceptual understanding, critical thinking, collaboration, and scientific reasoning, all of which are essential competencies for twenty-first-century learning.

Author's Contribution

E. Simamora: contributed to the conceptualization and design of the research, data collection, data analysis, and writing of the manuscript. M.A. Napitupulu: supervised the research process, provided academic guidance and theoretical input, and reviewed the final version of the manuscript. All authors have read and approved the final manuscript.

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