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Problem-based learning for developing students' critical thinking skills in human digestive system learning

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Abstract: This research seeks to evaluate the implementation of the Problem-Based Learning (PBL) to enhance students' critical thinking skills about the human digestive system content. This study method is pre-experimental, using a one-group pretest-posttest design. The research sample comprised 100 students, 45 males and 55 females, all in grade VIII at junior high schools in South Bolaang Mongondow Regency. Data-gathering methods included tests and questionnaires using the Guttman scale. The paired-samples t-test was used to see whether there was a significant difference between students' pretest and posttest results after PBL education. The data analysis indicated that the implementation of PBL significantly enhanced students' critical thinking (Sig. < 0.05). The N-Gain calculation result of 0.70 falls into the high category. The implementation of learning was assessed as good to very good, while students' answers to PBL were evaluated as very good. The results suggest that PBL is a pertinent and effective method for fostering critical thinking in junior high school science education, especially in contextual subjects closely linked to students' daily experiences.

Keywords: Critical thinking, human digestive system, learning implementation

Abstrak: Penelitian ini bertujuan untuk mengevaluasi implementasi Pembelajaran Berbasis Masalah (PBL) untuk meningkatkan kemampuan berpikir kritis siswa tentang konten sistem pencernaan manusia. Metode penelitian ini adalah pra-eksperimental, menggunakan desain pretest-posttest satu kelompok. Sampel penelitian terdiri dari 100 siswa, 45 laki-laki dan 55 perempuan, semuanya di kelas VIII SMP di Kabupaten Bolaang Mongondow Selatan. Metode pengumpulan data meliputi tes dan kuesioner menggunakan skala Guttman. Uji t sampel berpasangan digunakan untuk melihat apakah ada perbedaan signifikan antara hasil pretest dan posttest siswa setelah pendidikan PBL. Analisis data menunjukkan bahwa implementasi PBL secara signifikan meningkatkan kemampuan berpikir kritis siswa (Sig. < 0,05). Hasil perhitungan N-Gain sebesar 0,70 termasuk dalam kategori tinggi. Implementasi pembelajaran dinilai baik hingga sangat baik, sedangkan jawaban siswa terhadap PBL dinilai sangat baik. Hasil penelitian menunjukkan bahwa PBL merupakan pembelajaran yang tepat dan efektif untuk menumbuhkan berpikir kritis dalam pendidikan sains di sekolah menengah pertama, terutama pada mata pelajaran kontekstual yang terkait erat dengan pengalaman sehari-hari siswa.

Kata kunci: berpikir kritis, sistem pencernaan manusia, implementasi pembelajaran

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INTRODUCTION

Critical thinking is recognized as a core competency for the 21st century and must be developed through active learning (Akhwani & Rahayu, 2021). Therefore, schools need to equip students with these skills to respond to contemporary challenges. Critical thinking enables learners to make informed decisions and manage the demands of modern life. Critical thinking is crucial for improving the quality of life in the 21st century (Cacik & Widiyanti, 2024; Damopolii et al., 2022; Fitriyanti et al., 2025; McGill and Bax, 2011). Critical thinking skills are an essential asset in further education, the workplace, and social life

because they help students adapt to change and make responsible decisions. Therefore, it is crucial for teachers to enhance critical thinking to support students now and in the future.

Critical thinking refers to the ability to use knowledge to understand and solve problems (Juliyantika & Batubara, 2022). As a HOTs, it requires students to reason deeply, analyze information, formulate concepts, and draw on evidence to make sound judgments. It also helps learners respond appropriately to new situations and construct well-founded arguments (Putri et al., 2024). For this reason, critical thinking should be taught explicitly across subjects. In science education, it enables students to link scientific concepts to everyday situations (Diana et al., 2022). Teachers therefore need to adopt creative and innovative approaches that help students actively construct knowledge and enhance critical thinking (Rahayu et al., 2022).

The promotion of critical thinking in scientific education continues to be an important challenge. Abrami et al. (2015) found that critical thinking does not develop automatically through conventional instruction; rather, it requires explicit and well-structured teaching strategies that foster interpretation, analysis, evaluation, and inference. Similarly, Changwong et al. (2018) reported that, among 6,235 students across ten provinces in Thailand, the mean critical thinking score was only 36.5%, and just 2.09% met the passing standard. These findings suggest that traditional instruction does not adequately develop critical thinking. The conventional national curricula generally demonstrated weaker critical thinking skills than those enrolled in programs that explicitly integrated critical thinking (Johnston et al., 2023).

While numerous countries have integrated critical thinking into their science curricula, teachers often lack sufficient knowledge of how to teach it effectively, making curriculum goals difficult to achieve (Liu et al., 2024). Meirbekov et al. (2022) similarly emphasized that critical thinking is now regarded as a fundamental student competency, yet its classroom implementation remains inadequate in many education systems. This concern is reinforced by evidence that secondary school students often struggle with interpretation, analysis, evaluation, and inference—skills that are also assessed internationally through programs such as PISA (Tiruneh et al., 2017).

Agviolita et al. (2022) discovered that students' critical thinking in science was deficient and needed more efficacious educational methods. Iftiah et al. (2023) discovered that the students had inadequate skills. They articulated that these talents have not been fostered by educators, with one contributing factor being the pedagogical methods used during instruction. Damopolii et al. (2025) found that junior high school students exhibit deficient critical thinking. In alignment with this conclusion, Nunaki et al. (2023) and Nurhidayah et al. (2025) indicated that problem-based learning (PBL) enhances critical thinking by actively involving students in problem-solving activities. Melisa et al. (2025) discovered that student-centered learning approaches enhance critical thinking and improve comprehension of scientific subjects.

Preliminary observations showed that science instruction at the participating schools remained predominantly teacher-centered. Students often memorized concepts from textbooks or teachers' explanations through one-way instruction, which contributed to low attainment of the minimum mastery criterion of 75, particularly in the human digestive system topic. The limited use of PBL meant that instruction remained conventional and did not adequately promote students' independence or critical thinking. The human digestive

system is a science topic taught in Grade VIII that provides substantial opportunities to develop critical thinking. In addition to learning about digestive structures, functions, and processes, students can examine real issues such as digestive disorders, unhealthy eating patterns, and lifestyle habits that affect organ health (Dhaniawaty et al., 2021). However, students often find it difficult to connect theoretical concepts with problems in their everyday surroundings, which can lead to a passive understanding of the topic.

The digestive system material is difficult to learn because it is related to physiology and anatomy, where the teacher's teaching method focuses on memorization, which results in students not understanding the material (Setyantoko et al., 2023). Memorization-oriented learning is not effective for developing critical thinking (Mareti & Hadiyanti, 2021), In contrast, science education requires students to synthesize, evaluate, and analyze information to comprehend concepts and solve real-world problems (Nabila et al., 2025; Sa'adah et al., 2022). An innovative approach is therefore needed to shift instruction from teacher-centered to student-centered learning. The topic is particularly well suited to PBL because concepts such as digestive processes, enzymes, and organs can be explored through authentic cases involving digestive disorders, food choices, and lifestyle habits. In this context, PBL is an appropriate solution to improve students' critical thinking.

PBL is a collaborative instructional approach that uses authentic problems as a starting point for developing students' thinking skills (Misla & Mawardi, 2020). It presents learners with problems that require higher-order thinking to resolve (Butar-butar et al., 2022). In PBL, problems become the central focus of classroom activities, encouraging students to collaborate and think critically. Authentic problems trigger the learning process (Suwarni, 2019), while students analyze issues, seek and process information, discuss possible explanations, and draw conclusions from scientific evidence (Damopolii et al., 2018). By placing students in real-world situations that demand evidence evaluation and creative solutions, PBL supports the development of critical thinking (Rizkianto & Murwaningsih, 2018). The model is grounded in constructivism because students construct understanding as they work through contextual problems.

A number of studies have been conducted showing that PBL can improve students' critical thinking skills and learning outcomes (Hartati & Sholihin, 2015; Karvandi et al., 2024; Mandagi et al., 2021; Nafiah & Suyanto, 2014). Studies have also shown that PBL is effective for developing critical thinking in lessons on the human digestive system (Adhitya et al., 2023; Malasugi et al., 2025; Theresia & Silaban, 2024). PBL gives students opportunities to work with peers to identify solutions to the problems they encounter, thereby supporting task completion (Nirwana et al., 2022). As students gather information from different sources, discuss alternatives, and work toward shared goals, they practice the processes that underpin critical thinking (Ningrum et al., 2023). Overall, prior findings suggest that PBL has considerable potential to ienhance critical thinking in digestive system instruction. Nirwana et al. (2022) therefore recommended further research on the effectiveness of PBL for developing students' critical thinking skills. Based on this background and the preliminary observations, this study examined the implementation of PBL to improve students' critical thinking.

METHOD

This quantitative study used a pre-experimental one-group pretest–posttest design. Students completed a pretest before the PBL intervention and a posttest after instruction to identify changes in their critical thinking skills. The study was conducted in four junior high schools in South Bolaang Mongondow Regency. Participants were 100 Grade VIII students, comprising 45 boys and 55 girls. They were selected through simple random sampling from the participating schools. Each Grade VIII student had an equal chance of being included, regardless of academic ability, gender, or class background.

Data were collected using a written test on the human digestive system administered before and after instruction, a Guttman-scale observation sheet to assess learning implementation, and a Guttman-scale questionnaire to measure students' responses to PBL. The test consisted of 10 multiple-choice items aligned with critical thinking indicators (Adhitya et al., 2023). It was administered twice, with the order of items randomized between the pretest and posttest. The critical thinking indicators assessed by the test are presented in Table 1.

Table 1. Critical thinking skill indicators (Adhitya et al., 2023)

Indicator	Number of Items
Formulating the central problem	2
Identifying relevant facts	2
Constructing arguments	2
Recognizing bias	2
Decision making	2

Table 2. Learning implementation indicators (Adhitya et al., 2023)

	Activity Phase / Indicator	Number of Items
Preliminary activities	Orientation	3
	Aperception	3
	Motivation and objectives	3
Core activities	Orienting students to the issue	3
	Organizing students for learning	2
	Guiding students in investigations	2
	Developing and presenting work	3
	Analyzing and evaluating the problem-solving process	3
Closing activities		3

The critical thinking test was reviewed by four validators, all of whom were science teachers in South Bolaang Mongondow Regency. The instrument obtained a validity coefficient of 0.60 and a reliability coefficient of 0.60. According to Arikunto (2019), a reliability coefficient between 0.60 and 0.79 is categorized as high; therefore, the instrument was considered suitable for research use. Nunnally (1994) also noted that a reliability coefficient of 0.60 is acceptable for exploratory research, although a value of 0.70 or higher is preferable when greater precision is required. Accordingly, the test was

considered sufficiently reliable for this study. A 25-item learning-implementation questionnaire was also administered; its indicators are shown in Table 2.

The learning-implementation questionnaire was reviewed by four science teachers in South Bolaang Mongondow Regency. It obtained a validity coefficient of 0.50 and a reliability coefficient of 0.70, indicating that the instrument was valid and reliable. A 15-item student response questionnaire was then administered, with its indicators presented in Table 3.

Table 3. Student response indicators for learning (Adhitya et al., 2023)

Indicator	No. of Items
Interest in participating in learning	4
Ability to identify the main problem	3
Acquisition of problem-solving skills in science learning	3
Perceived benefits of science learning	3
Ease of understanding the learning materials	2

The student response questionnaire was also reviewed by four science teachers in South Bolaang Mongondow Regency. It obtained a validity coefficient of 0.40 and a reliability coefficient of 0.90; therefore, it was considered suitable for use in this study.

The data analysis focused on three domains: students' critical thinking abilities, learning completion, and students' responses to PBL. Critical thinking scores were obtained from the pretest and posttest outcomes. Prior to parametric analysis, the data were assessed for normality using the Kolmogorov–Smirnov test, given that the sample comprised 100 students. The significant values for both the pretest and posttest data exceeded 0.05, indicating normal distribution and compliance with the requirements for a paired-samples t-test. The paired-samples t-test was used to determine whether there was a significant difference between students' pretest and posttest results. The enhancement in critical thinking was assessed using N-gain in Microsoft Excel and analyzed according to the criteria Hake (1998).

Learning implementation was examined to determine the extent to which the PBL model was carried out as intended. Observation scores were converted to percentages by comparing the mean score for each item with its maximum possible score. The student response questionnaire was analyzed in the same way to determine students' perceptions of PBL, and the standard deviation was also calculated. Learning implementation and student response results were interpreted using the percentage criteria by Fhun and Koriaty (2024).

RESULTS AND DISCUSSION

The Kolmogorov–Smirnov test was first used to assess the normalcy of pretest and posttest results for critical thinking. A paired-samples t-test was used to ascertain if the scores exhibited significant differences post-PBL training, followed by an N-gain analysis to evaluate the degree of enhancement in the human digestive system issue. Table 4 presents the findings of descriptive statistics, normality tests, and paired-samples t-tests, while Table 5 displays the N-gain results.

Table 4. Normality and paired t-tes results for students' critical thinking skills

Variable	Mean ± SD	Normality	Paired t-test		
		Sig.	t	df	Sig.
Pretest	49.20 ± 15.80	0.200	24.25	99	0.001
Posttest	84.60 ± 10.20	0.200			

As shown in Table 4, the mean critical thinking score increased from 49.20 ± 15.80 on the pretest to 84.60 ± 10.20 on the posttest. The paired-samples t-test yielded a p-value of less than 0.001, indicating a statistically significant difference between students' pretest and posttest critical thinking scores. The results demonstrate that PBL teaching on the human digestive system was associated with enhanced critical thinking skills. The normality test confirmed that the data met the criteria for parametric analysis, while the paired-samples t-test and N-gain analysis indicated an improvement from pretest to posttest.

The improvement in students' critical thinking suggests that problem-solving-centered learning can actively engage students in analysis, evaluation, and decision making. This interpretation is consistent with constructivist theory, which views knowledge as something students actively construct through interaction with authentic problems and meaningful learning experiences. Based on a constructivist perspective, students build understanding through interaction with their environment and engagement with real-world problems. This view reflects constructivist perspectives associated with Piaget and Vygotsky (Ghaour, 2018). In PBL, contextual problems prompt students to develop their own understanding through analysis and problem solving. This interpretation is consistent with findings from Adhitya et al. (2023) and Theresia and Silaban (2024), who reported that PBL can improve critical thinking in science-learning contexts.

The overall N-gain score of 0.70 was classified as high, reinforcing the conclusion that PBL can support the development of critical thinking skills. This is especially relevant in science learning, where students are expected to analyze evidence, evaluate ideas, solve contextual problems, and make informed decisions. The result is consistent with Hartati and Sholihin (2015) and Mandagi et al. (2021), who found that students taught through PBL showed greater gains in critical thinking than those taught through conventional approaches.

Table 5. N-gain results for critical thinking indicators

No.	Critical Thinking Indicator	P1	P2	N-Gain	Criteria
1	Formulating the main problem	9.8	14.9	0.50	Medium
2	Identifying relevant facts	10.2	15.4	0.50	Medium
3	Constructing arguments	9.6	18.2	0.90	High
4	Recognizing bias	9.4	17.8	0.90	High
5	Decision making	10.0	18.6	0.90	High

Notes:
P1 = Pretest
P2 = Posttest

Table 5 indicates that enhancement varied across the assessed critical thinking skills. The minimum N-gain score was 0.50 for articulating the primary issue, categorizing it as

medium. The most significant improvement was seen in decision making, with an N-gain of 0.90 classified as strong. The average score rose from 49.20 on the pretest to 84.60 on the posttest, resulting in an N-gain of 0.70, classified as high. The evaluation of learning implementation during PBL teaching was conducted using an observer-administered questionnaire.

Improvement was not uniform across all critical thinking indicators. Formulating the central problem and identifying relevant facts categorized as medium. Although students began to identify problems and supporting information, these skills still required further reinforcement. This pattern may be related to their previous learning experiences, which were more strongly oriented toward memorization; consequently, students may not yet have been accustomed to independently identifying problems. This pattern can be explained by Raj et al. (2022) view that identifying problems and relevant facts requires sustained practice and habituation. Students accustomed to memorization-based learning may find the initial stages of critical thinking particularly challenging. This interpretation is consistent with Rosmalinda et al. (2021), who found that junior high school students' ability to identify problems and relevant information in PISA-type questions was generally in the low-to-medium range.

Constructing arguments, recognizing bias, and making decisions each achieved high category. These substantial gains suggest that PBL effectively trains students to formulate logical arguments, evaluate information critically, and make decisions based on scientific evidence. This is consistent with the nature of PBL, which situates students in authentic problems that require them to discuss alternatives, test their arguments, and select the most appropriate solution. This pattern also aligns with (Facione et al. (2013) view that critical thinking involves analysis, evaluation, inference, and evidence-based decision making. Group discussion, analysis of authentic cases, and presentation of findings are central features of PBL. These activities encourage students to construct logical arguments, evaluate information, and select appropriate solutions. This result is consistent with Fauziyah et al. (2022), and Nafiah and Suyanto (2014), who reported that PBL significantly improves students' argumentation and decision-making skills.

Overall, these findings support the constructivist view that knowledge is actively built through meaningful learning experiences. PBL gives students opportunities to construct understanding through problem solving rather than simply receiving information from the teacher. The results are also consistent with Adhitya et al. (2023) and Theresia and Silaban (2024), who found that PBL can strengthen critical thinking, particularly in evaluation and decision making. The resulting implementation percentages are presented in Figures 1 and 2.

Observers evaluated students' activities across three components: instroduction, core, and closing activities. Introduction activities, including prayer and attendance checking, were rated at 87.2% in the first meeting and 90.6% in the second. Core activities—including orientation of problem, organizing students, guiding individual and group investigations, developing and presenting work, and analyzing and evaluating the problem process—were rated at 74.8% in the first meeting and 79.3% in the second. Closing activities, such as reviewing the lesson, were rated at 83.6% and 88.1%, respectively. The improvement in critical thinking was also accompanied by learning-implementation scores in the good-to-very-good range. Introduction activities received high percentages in both

meetings (87.2% and 90.6%, respectively), suggesting that the teacher successfully established students' readiness and motivation at the start of instruction.

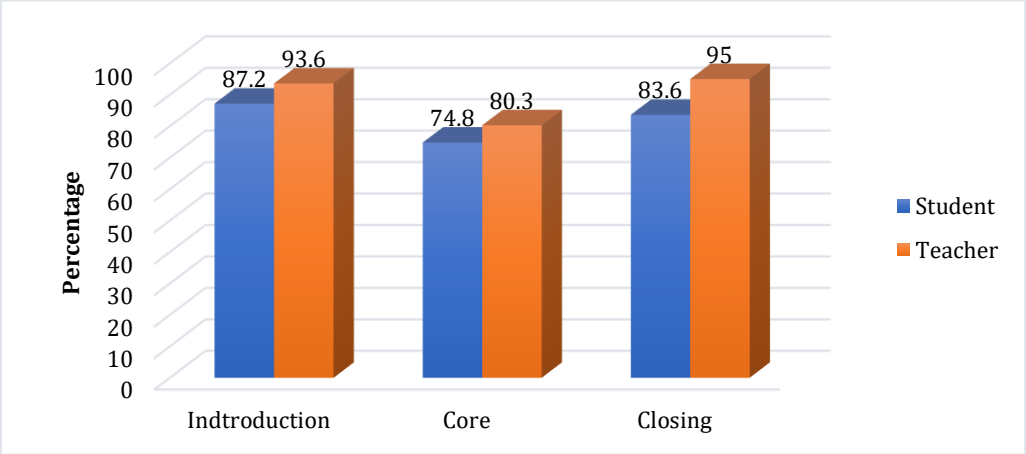

Fig. 1. Learning implementation during the first meeting

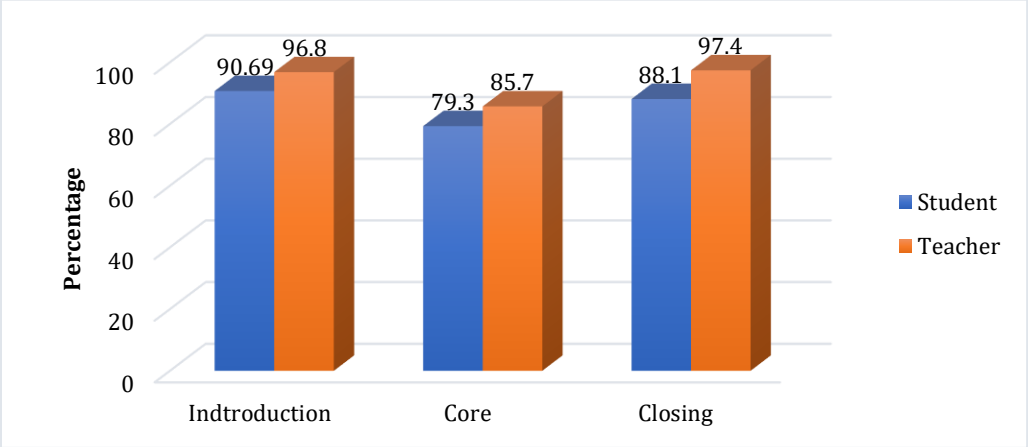

Fig. 2. Learning implementation during the second meeting

The percentage for core activities increased from 74.8% in the first meeting to 79.3% in the second. This increase suggests that students became increasingly familiar with PBL stages, including problem orientation, investigation, and group discussion. The success of a learning model depends heavily on the consistent implementation of each stage (Aprillia et al., 2025; Aristaningsih et al., 2025; Mustofa et al., 2024; Nasir et al., 2020). The stronger implementation of PBL in this study therefore likely contributed to the enhancement in students' critical thinking. Closing activities also improved, rising from 83.6% to 88.1%. This increase suggests that reflection and evaluation were carried out more effectively in the second meeting. Consistent implementation of these stages is important because it helps ensure that every part of PBL supports the development of students' critical thinking. This result is consistent with Ananda and Fauziah (2022), who reported that effective PBL implementation is associated with improved critical thinking. Students' responses to PBL, summarized across five indicators, are presented in Table 6.

Table 6. Students' responses to learning (N = 100)

No.	Indicator	Yes (%)	No (%)
1	Interest/enjoyment	88.2 ± 3.1	11.8 ± 3.1
2	Ease of identifying problems	90.5 ± 2.7	9.5 ± 2.7
3	Problem-solving skills	89.1 ± 2.9	10.9 ± 2.9
4	Perceived benefits	93.4 ± 1.8	6.6 ± 1.8
5	Ease of understanding	85.0 ± 0.0	15.0 ± 0.0

Notes:
1. N = 100 students
2. The Yes and No columns report the percentage of students responding to each indicator, together with the standard deviation (SD).

Across all indicators, positive responses ranged from 85.0% to 93.4%, indicating that students had highly favorable perceptions of the PBL. The strongest perception was related to the benefits of the learning experience, while the lowest score was associated with ease of understanding, suggesting that although the approach was effective and engaging, additional instructional support may be needed to help some students fully understand complex concepts. Overall, these findings suggest that the implementation of PBL was well received and effectively promoted student engagement, problem-solving abilities, and understanding

These positive responses suggest that PBL supports not only cognitive outcomes but also affective aspects of learning, including interest and motivation. This is important because motivated students are more likely to engage actively in the learning process, which can, in turn, strengthen critical thinking. This finding is consistent with Ananda and Fauziah (2022) and Ningrum et al. (2023), who noted that PBL can create meaningful and enjoyable learning experiences. The contextual nature of the human digestive system topic may also have strengthened the effectiveness of PBL by helping students connect scientific concepts with everyday life. Learning that incorporates authentic problems can foster deeper scientific reasoning, as Diana et al. (2022) emphasized in highlighting the importance of connecting science concepts with real-life contexts.

CONCLUSION

The implementation of PBL in instruction on the human digestive system was associated with improved students' critical thinking skills. The improvement was reflected in higher posttest scores, and an N-gain score in the high category. Gains were evident across all indicators, with the strongest improvements in constructing arguments, recognizing bias, and decision making. Learning implementation was rated from good to very good, and students' responses to PBL were in the very good category. These findings indicate that PBL is a relevant and effective alternative for developing critical thinking in junior high school science learning, particularly for contextual topics that are closely connected to students' everyday lives.

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