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The Power of Problem-Based Learning in Enhancing Critical Thinking Skills: A Study on Human Respiratory System

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Abstract

Critical thinking skills are one of the essential competencies that must be developed in elementary school students in the modern era. This ability serves as a foundation for students to understand problems, analyze information, and make informed decisions in subsequent educational levels. However, in practice, students' critical thinking skills are still relatively low, particularly in science learning. This study aims to investigate the effect of implementing problem-based learning (PBL) models on the critical thinking skills of 5th-grade students on human respiratory system material. The study employed a quantitative approach with a quasi-experimental method using a pretest-posttest nonequivalent control group design, which involved administering a pretest before treatment and a posttest after treatment to both the experimental and control groups. Data were analyzed using ANCOVA to determine differences in critical thinking skills after treatment. The results showed that the PBL model had a significant effect on improving students' critical thinking skills. This was evidenced by the ANCOVA analysis results, which showed an F-count of 11.414, greater than the F-table of 2.74, with a significance value of 0.001, which is less than 0.05. These findings indicate that the alternative hypothesis is accepted, and it can be concluded that the learning model has a significant effect on critical thinking skills of students on the human respiratory system material. The results of the further LSD test demonstrate that PBL has greater potential to improve students' critical thinking compared to the conventional model. This study recommends that teachers consistently apply PBL models in science and other subjects to encourage students to think deeply, systematically, and analytically

Keywords: Problem-Based Learning; Critical Thinking; Higher-Order Thinking Skills; Human Respiratory System

1. Introduction

Recent major transformations in the global economy have significantly impacted the high volume of international commercial transactions, requiring organizations across various sectors, including production, marketing, finance, education, and others, to make strategic adjustments (Petricevic & Teece, 2019). This transformation has also led to increased competition intensity among organizations and countries, forcing organizations to adapt to ensure their survival in their respective markets; otherwise, the risk of competition will threaten their existence (Kang & Na, 2020). One area where an organization can achieve a competitive advantage is in its human resources, which are considered one of the most important resources and sources of success (Pahuja et al., 2024). However, it is widely understood that in high-quality educational organizations, exploration and development are drivers of national development and individual satisfaction (Kang & Na, 2020). Moreover, universities worldwide, regardless of their background, strive to become centers of excellence where information is obtained and disseminated to those who need it through teaching, learning, exploration, and partnerships (Nopas & Kerdsomboon, 2024). Therefore, universities, like other organizations, need to reevaluate their ways of working and building sustainable competitive advantages. The higher education sector

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faces intense competition globally, and universities need to work harder to enhance their competitive advantages (Alfawaire & Atan, 2021). Consequently, human resources must be equipped with good skills.

One essential skill that needs to be mastered is critical thinking. This skill is a necessity for individuals to solve problems, innovate, and adapt in the era of technological advancements. For example, in the healthcare sector, this skill is crucial for healthcare professionals, particularly in clinical pharmacology, where decision-making directly impacts patient care (Firman et al., 2025). Additionally, critical thinking is a crucial element of complex problem-solving, which will facilitate the provision of clinical care with proper professional behavior and is now considered a vital element in dental education (Sireerat et al., 2025). Critical thinking skills are also essential for sports management (Cook, 2025) and business graduates (Rossouw & Steenkamp, 2025), Therefore, it can be said that this skill is highly important in the 21st century. Critical thinking has its roots in the works of prominent figures such as Socrates, Thomas Aquinas, Francis Bacon, Rene Descartes, John Locke, and Sir Isaac Newton in its early stages. More modern contributions can be attributed to John Dewey, Ludwig Wittgenstein, and Jean Piaget, among others. The work completed by Robert Ennis in the 1960s gave rise to critical thinking skills being taught in classrooms and reflected in the workplace (Murawski, 2022). The ideal critical thinker, in his writing, tends to reach "right" decisions, convey their position honestly and clearly, consider other perspectives, strive to obtain adequate information, and avoid intimidation or confusion. Furthermore, the critical thinker has the ability to focus on a question, analyze and argue, assess the credibility of a source, make and appreciate judgments, clarify and refine their perspectives, support their perspectives appropriately, and imaginatively assume and integrate the logic of a perspective with sensitivity to others (van Peppen et al., 2021).

Comparative studies of several countries analyzed, such as those based on the vision outlined in Thailand 4.0, have shown that critical thinking skills have become one of the main pillars of the new knowledge-based economy. However, a 2015 study by the Thailand Research Fund, which evaluated the logical and analytical thinking skills of 6,235 students in ten provinces in Thailand, found that the average score was 36.5%, with only 2.09% of all students passing. Aware of the severity of this crisis, nine experts met in August 2017 as a focus group and were tasked by researchers to help develop a new critical thinking management learning model (Changwong et al., 2018). Similar studies have also been found in Australia, where low student motivation, misconceptions about learning objectives, and lack of student readiness for high-level thinking (Gunawardena & Wilson, 2021). Currently, the Indonesian government through the Ministry of Education has launched a curriculum called the independent curriculum, which aims to improve students' critical thinking skills (Waruwu et al., 2024). Critical thinking or critical reasoning is key to academic success and becoming an active part of a world that is constantly changing (Syamratulagi et al., 2025).

In modern society, critical thinking is a primary goal of the learning process at every level of education, which is in line with the developments of the 21st century, where students experience many changes in aspects of life, influenced by various factors such as rapid technology and information, economy, social, and culture. Therefore, critical thinking skills are used as a filter for all forms of change to determine which ones should be applied and which ones should not. According to Reyk et al., (2022), critical thinking skills are a mental process for analyzing obtained information. Meanwhile, information obtained through observation, experience, communication, or reading; therefore, teachers must provide opportunities for students to convey their ideas or opinions on a problem so that students can develop their critical thinking skills. Critical thinking is one of the thinking skills that is closely related to a person's cognitive abilities (Song & Cai, 2024). According to Ennis (2018), critical thinking must be understood in general about fact analysis, evidence, observation, argument, and other available materials to form an assessment based on rational, skeptical, and impartial application. Furthermore, critical thinking is also defined as a reflection that does not take for granted one's understanding or others' understanding, but rather analyzes it in a historical context and particularly in the context of emerging issues.

Critical thinking skills become the most important aspect in modern education, as they can prepare the younger generation to have quality in analytical, logical, and independent thinking. Meanwhile, the results of Raj et al. (2022) study on "the importance of critical thinking in education" show that critical thinking skills taught in class have a significant impact on the future work development process. In line with this, Sasmita et al. (2023) explain that critical thinking skills are essential to face global challenges and various problems that cannot be controlled. Critical thinking is a complex cognitive process that involves the ability to think clearly and rationally, understand logical relationships between ideas, evaluate arguments, and identify inconsistencies in reasoning, in addition to being essential for effective problem-solving, informed decision-making, and knowledge mastery (Gerlich, 2025). According to Ibragimova et al. (2024), critical thinking skills are widely recognized as key skills in education that enable students to think critically, analyze information, and make correct decisions. Therefore, critical thinking skills must be instilled through the learning process for elementary school students. This is because elementary school students are at a crucial stage of cognitive development, and at this age range, children begin to show more complex and logical thinking abilities compared to previous ages (Leasa et al., 2020). Meanwhile, students have shown a high level of curiosity, providing questions and

new explorations (Syifa et al., 2024). According to Khasanah et al. (2025), fifth-grade students tend not to receive passive information but actively seek clarity, praise opinions, and assess various alternatives before reaching a conclusion. Therefore, strengthening critical thinking skills in elementary school students is very relevant to the demands of modern education that emphasizes analytical, creative, and solution-oriented thinking.

In every subject matter taught by teachers to students, an active interaction is required to achieve an active learning process; therefore, teachers must be able to encourage students to analyze problem-solving in the subject matter taught and then convey it with consistent arguments or opinions. Therefore, one of the subjects that can encourage students' critical thinking skills is natural and social sciences. However, teachers must play a crucial role in fostering critical thinking skills in elementary school students in studying natural science subjects. The results of Mardiana et al. (2024), study show that teachers are not only responsible for delivering material but also as mentors who help students build knowledge independently. Additionally, teachers must also play an important role in providing learning resources that support the achievement of learning objectives and the teaching and learning process (Risandy et al., 2024). Meanwhile, at the fifth-grade level, the material on the human respiratory system is very suitable for training students' critical thinking skills. This is because the topic not only contains basic knowledge but also provides an opportunity for students to ask questions, analyze, and connect various concepts and functions of the human respiratory system. However, although developing critical thinking is a primary goal, many elementary school students still lack this skill. Usually, students can mention the parts of the respiratory organs, such as lungs, trachea, and bronchi, and explain the basic functions of these organs. However, when students are asked to explain how these organs work together or what happens if one of the organs is disrupted, many students still find it challenging to provide logical and in-depth answers.

In reality, many elementary school teachers still experience difficulties in implementing effective methods to develop students' critical thinking skills. A student is considered to be able to think critically if they can think logically, structured, reflectively, and productively when making considerations and decisions in the learning process in class or outside of class. One of the learning models often used to improve critical thinking skills is problem-based learning (PBL). According to Leasa et al. (2021) , learning with PBL helps students who have previously experienced learning failure and require additional academic skills to experience an authentic learning process; furthermore, this learning process does not only focus on the information delivered by the teacher, and thus PBL learning provides a very motivating learning challenge for students with limitations to develop their academic potential. The study by Yu & Zin, (2023) analyzed 20 articles and found that integrating CT elements into PBL effectively improves students' CT. PBL is a learning model based on real situations, meaning that students' daily experiences can help solve problems in every learning process in class (Leasa et al., 2023). PBL places students at the center of learning, where they work together to solve problems. In this way, students not only gain knowledge but also practice analysis, evaluation, and in-depth thinking skills through discussions and explorations.

PBL emphasizes learning driven by discovery and collaboration, allowing students to engage deeply with the material and develop critical thinking skills (Hafizah et al., 2024). According to Ahmad et al. (2025) , the problem-based learning model is an approach that focuses on developing cognitive skills, problem-solving skills, communication skills, evaluation skills, cooperation, and talent development together with subject knowledge; therefore, PBL is implemented through a continuous learning process and involves students in collaborative solutions to real-world problems. The study by Ansya & Salsabilla, (2024) shows that problem-based learning significantly improves students' critical thinking skills and increases active engagement, courage to express opinions, and enthusiasm for learning. However, to improve students' critical thinking skills through problem-based learning, teachers must understand the steps in the problem-based learning model. Through PBL, students will be faced with real problems related to the human respiratory system. Students will then be guided to analyze problems, seek information, and formulate solutions independently or in groups. Learning using the PBL model can directly train the five aspects of critical thinking according to (Ennis, 2011), namely providing simple explanations, building basic skills, drawing conclusions, providing further explanations, and compiling strategies and tactics, all of which are adjusted to the cognitive development of elementary school students. Therefore, this study aims to determine the effect of the PBL model on critical thinking of students on the material of the human respiratory system.

2. Method

This study employed a quantitative method with an experimental approach. The type of experiment used was quasi-experimental, involving two groups: an experimental group and a control group. The research design used was pretest-posttest nonequivalent control group design, which involves a pretest before treatment and a posttest after treatment. This design is a method used to estimate the relative effect of two or more different treatment conditions. In its simplest form, this method involves a comparison between two treatment conditions. These conditions can be alternative interventions, such as a new treatment and a standard treatment, or one condition can be a control without intervention.

Participants in this design can be individuals or groups of individuals, such as classes, communities, or companies. Each treatment being compared is applied to a different group of participants. After the treatment is applied, the relative effect is assessed by comparing the performance between groups based on the measured outcomes (Reichardt, 2005).

The population in this study was all fifth-grade students at SD Negeri 87 Ambon, totaling 3 classes. The sample used in this study was 2 classes, selected using Random Sampling as the sampling method. Noor et al. (2022) explain that simple random sampling is a technique often used in quantitative research that uses surveys as instruments. This technique is considered effective, especially when the population is homogeneous and evenly distributed. In the selection process, each individual has an equal chance of being selected because the sample determination depends entirely on luck. Although it has advantages such as ensuring equal probability and being representative of the population, simple random sampling also has some limitations. This process can be complex, especially when there is no adequate and easily accessible population list. Additionally, simple random sampling can also pose challenges when the population being studied is heterogeneous and widespread. The learning process was conducted in 4 meetings in the experimental class and 4 meetings in the control class, with the same material, namely the parts of the human respiratory organs and their functions, the process of human respiration, disorders, and how to maintain human respiratory organs. The data collection technique in this study was observation. The test used was a written test in the form of essay questions for pretest and posttest.

The research instrument test has been conducted to ensure its validity and reliability before use. In the validity test, 10 questions were tested on 25 respondents who were sixth-grade students. The results showed that 6 questions were declared valid and could be used in the study, while 4 questions were declared invalid and did not meet the expected criteria. Furthermore, the reliability test of the instrument was conducted to measure the level of consistency and reliability of the instrument questions. The results showed that the Cronbach's Alpha value obtained was 0.756, which was greater than 0.60. This means that all items in the instrument questions have a good level of feasibility to measure the learning outcomes of participants. Before conducting further data analysis, the prerequisite tests for data analysis will be conducted to ensure that the data used meet the required assumptions. The prerequisite tests to be conducted include normality tests and homogeneity tests. Normality tests will be used to ensure that the data used have a normal distribution, while homogeneity tests will be used to ensure that the variance of data between groups being compared is homogeneous. After all prerequisite tests are met, the Ancova (Analysis of Covariance) test will be conducted using the SPSS 27 windows computer program to test the research hypothesis. The Ancova test will be used to analyze the effect of the independent variable on the dependent variable, while controlling for the effect of relevant covariate variables (Lüdtke & Robitzsch, 2025). By using the Ancova test, researchers can obtain more accurate results that can be better interpreted (Schwarz, 2025).

3. Results

The students' critical thinking skills were assessed by administering a pretest to both the experimental and control groups before commencing the learning process using the prepared independent curriculum teaching module. Subsequently, at the end of the learning process, the researcher administered a posttest to the students.

Table 1 Overall Percentage Data of Students' Critical Thinking Skills in the Experimental Group

Indicator	Number of Participants	Percentage (%)	Category	Number of Participants	Percentage (%)	Category
	Pretest Results			Posttest Results		
Giving simple explanations	1	2.8	Very Good	3	8.5	Very Good
	10	28.5	Good	10	28.5	Good
	23	65.7	Fair	19	54.2	Fair
	1	2.8	Poor	2	5.7	Poor
	0	0	Very Poor	1	2.8	Very Poor
Building Basic Skills	1	2.8	Very Good	7	20	Very Good
	11	31.4	Good	13	37.1	Good

Indicator	Number of Participants	Percentage (%)	Category	Number of Participants	Percentage (%)	Category
	14	40	Fair	12	34.2	Fair
	9	25.7	Poor	2	5.7	Poor
	0	0	Very Poor	1	2.8	Very Poor
Drawing Conclusions	0	0	Very Good	14	40	Very Good
	5	14.2	Good	4	11.4	Good
	12	34.2	Fair	7	20	Fair
	18	51.4	Poor	10	28.6	Poor
	0	0	Very Poor	0	0	Very Poor
Providing Further Explanation	0	0	Very Good	16	45.7	Very Good
	2	5.7	Good	3	8.6	Good
	11	31.4	Fair	6	17.1	Fair
	21	60	Poor	9	25.7	Poor
	1	2.8	Very Poor	1	2.8	Very Poor
Developing Strategies and Tactics	0	0	Very Good	7	20	Very Good
	27	77.1	Good	19	54.3	Good
	5	14.3	Fair	8	22.9	Fair
	3	8.5	Poor	1	2.8	Poor
	0	0	Very Poor	0	0	Very Poor
Total	35	100		35	100	

Based on the scores obtained by students in the experimental group, the results show that the percentage of indicators for providing simple explanations was 2.8% of students, which increased to 8.5% of students in the very good category. For the indicator of building basic skills, 2.8% of students were in the very good category, which increased to 20%. The indicator of concluding showed 0% of students initially, but increased to 31.4% of students in the very good category. The indicator of providing further explanations showed 0% of students initially, but increased to 17.1% of students in the very good category. Lastly, the indicator of regulating strategies and tactics showed 0% of students initially, but increased to 20% of students in the very good category

The pretest and posttest results in the experimental group indicate that the PBL learning model has a significant impact on improving students' critical thinking skills. This improvement occurs because the PBL learning model places students at the center of learning by presenting them with real-world problems to analyze and solve. This process also engages students actively in identifying problems, seeking information, discussing, and drawing conclusions. These activities directly train analytical skills, logical reasoning, and argumentation, so that each indicator of critical thinking develops better. In other words, PBL not only conveys material but also provides a learning experience that encourages students to think at a higher level.

Tabel 2 Percentage of Overall Students in Critical Thinking of Control Group

Indicator	Number of Participants	Percentage (%)	Category	Number of Participants	Percentage (%)	Category
	Pretest Results			Posttest Results		
Giving simple explanations	0	0	Very Good	0	0	Very Good
	1	2.8	Good	5	14.3	Good
	33	94.3	Fair	21	60	Fair
	1	2.8	Poor	3	8.5	Poor
	0	0	Very Poor	6	17.1	Very Poor
Building Basic Skills	0	0	Very Good	1	2.8	Very Good
	1	2.8	Good	4	11.4	Good
	32	91.4	Fair	21	60	Fair
	2	5.7	Poor	8	22.8	Poor
	0	0	Very Poor	1	2.8	Very Poor
Drawing Conclusions	1	2.8	Very Good	0	0	Very Good
	0	0	Good	3	8.6	Good
	13	37.1	Fair	16	45.7	Fair
	20	57.1	Poor	15	42.9	Poor
	1	2.8	Very Poor	1	2.8	Very Poor
Providing Further Explanation	0	0	Very Good	1	2.8	Very Good
	1	2.8	Good	4	11.4	Good
	12	34.3	Fair	8	22.9	Fair
	20	57.1	Poor	19	54.2	Poor
	2	5.7	Very Poor	3	8.6	Very Poor
Developing Strategies and Tactics	0	0	Very Good	0	0	Very Good
	4	11.4	Good	5	14.3	Good
	28	80	Fair	24	68.6	Fair
	3	8.6	Poor	6	17.1	Poor
	0	0	Very Poor	0	0	Very Poor
Total	35	100%		35	100%	

Based on the scores obtained by students in the control group, the results showed that the percentage of indicators providing simple explanations was 2.8% of students and decreased by 0% of students in the very good category. The indicator of building basic skills was 0% of students and increased by 2.8% of students in the very good category. The

indicator of concluding was 2.8% of students and decreased by 0% of students in the very good category. The indicator of providing further explanation was 0% of students and increased by 2.8% of students in the very good category. The indicator of regulating strategies and tactics was 0% of students and did not change by 0% of students in the very good category.

The results of the pretest-posttest showed that the traditional learning model (lectures) only had a very limited impact on stimulating students' critical thinking skills. This is because learning using the lecture method tends to make students passive, only listening to the teacher's explanation without the opportunity to discuss, ask questions, or solve problems. As a result, critical thinking skills such as analysis, reasoning, and strategy have not developed optimally. The lecture model focuses more on delivering material and memorization, so it does not train students to use higher-order thinking skills.

The normality test was conducted to determine whether the data was normally distributed or not. The researcher used the Shapiro-Wilk test because this method is considered most suitable for a sample size > 50 people. The test results showed that the data was considered normally distributed if the significance value was greater than 0.05. The Shapiro-Wilk for normality test used the residual values of the critical thinking post-test. The results showed that the data normality value was 0.085. Where, 0.085 > 0.05 means the data is normally distributed.

The homogeneity test was conducted on the pretest and posttest data in the experimental and control groups to determine whether the two sample classes had homogeneous variants or not. The hypothesis of the homogeneity test can be said to be homogeneous data if the significance value > 0.05, and the data is not homogeneous if the significance value < 0.05. The results of the homogeneity test showed that the Sig value was 0.565. Based on the predetermined criteria, it showed that 0.565 > 0.05, so the data was homogeneously distributed. The Ancova test was conducted to determine whether there was an effect of the problem-based learning model and traditional learning model on students' critical thinking on the material of the human respiratory system in class 5 of SD Negeri 87 Ambon. The results of data analysis using the Ancova test were conducted on the experimental group with 35 respondents. Meanwhile, in the control group with 35 respondents.

Table 3 Results of the ANCOVA Analysis

Dependent Variable: Posttest						
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	10296.011[a]	2	5148.005	52.478	<.001	0.610
Intercept	11.389	1	11.389	0.116	0.734	0.002
Pretest	8842.282	1	8842.282	90.137	<.001	0.574
Learning Model	1119.692	1	1119.692	11.414	0.001	0.146
Error	6572.575	67	98.098			
Total	267311.000	70				
Corrected Total	16868.589	69				
R Squared = .721 (Adjusted R Squared =.713)						

Based on the data in Table 3, the results of the ANCOVA test in the learning model column above can be concluded that the significance in the Learning Model is 0.001. The calculated F value is 11.414, and the F table value obtained from the data above is 2.74. The value of 2.74 was obtained using the formula df2 = n-k, df2 = 70 - (2+1), df2 = 69. To find the result of 2.74, the F table was adjusted based on the sample size minus the number of variables (independent and dependent), and thus the result of 2.74 was found. The hypothesis test was conducted to determine whether the hypothesis is accepted or rejected. According to the hypothesis calculation using the ANCOVA test through Univariate, which shows a significance result of 0.001, the ANCOVA test proves that F calculated > F table, resulting in 11.414 > 2.74 and a significance of 0.001 < 0.05, which states that Ho is rejected and Ha is accepted. It can be concluded that the learning model has a significant effect on critical thinking skills of students on the human respiratory system material.

Further testing using least significant difference (LSD) was conducted to obtain information about the differences in critical thinking skills between the PBL learning model and the conventional model. The data used were the corrected means for both learning models, as shown in Table 4.

Table 4 Results of the LSD Test of Critical Thinking by Learning Model

Learning Model	Mean Posttest	Corrected Mean	Notation LSD
PBL	64.37	63.82	a
Conventional	55.25	55.81	b

Table 4 shows that students' critical thinking skills, when taught using the PBL learning model, differ significantly from those taught using conventional learning models. The PBL learning model has greater potential to improve students' critical thinking compared to the conventional model.

4. Discussion

PBL is a powerful solution for teaching critical thinking skills. So far, teachers have understood what critical thinking is and the skills related to it. The main point is that these skills can be taught and, further, that critical thinking skills can be transferred to students' cognition through teaching. Critical thinking skills are taught in the context of science subjects, specifically in the topic of the human respiratory system. In this context, PBL can help teach critical thinking skills by identifying problems, collecting information, analyzing information, making conclusions, and evaluating solutions. Students are given problems related to the human respiratory system, such as "What happens if someone experiences difficulty breathing?" or "How can we increase lung capacity?". They then collect relevant information, such as the anatomy of the respiratory system, lung function, and factors that affect lung capacity. Next, students analyze the collected information and identify patterns and relationships between related concepts. They then make conclusions based on evidence and collected information about how to increase lung capacity. Finally, students evaluate the solutions they have found and consider the advantages and disadvantages of those solutions. By using the PBL approach, students can develop their critical thinking skills in the context of science subjects with the topic of the human respiratory system. Critical thinking skills taught through PBL can help students become more independent, creative, and able to solve problems in everyday life. Additionally, PBL can also help students understand science concepts better and develop their ability to analyze and evaluate information. In its implementation, PBL can be done by providing problems relevant to everyday life, dividing students into small groups, and asking them to work together to find solutions. Teachers can act as facilitators and provide guidance to students during the investigation and discovery process. Thus, PBL can be one of the effective learning approaches in teaching critical thinking skills in science subjects. Therefore, PBL can be one of the alternative learning approaches that can be used by teachers to teach critical thinking skills to students.

In teaching strategies and models, there are several key themes that can be used to teach critical thinking, such as the use of student-centered teaching methods, making the teacher a facilitator who facilitates in-depth learning, thinking skills, and domain knowledge, as well as someone who models thinking, makes thinking explicit and visible to everyone, and uses real-life problems to stimulate learning. To make critical thinking skills an integral part of sustainable lifelong learning, curriculum reform requires that these skills be listed as learning outcomes in the curriculum. This is similar to the argument of Ho et al., 2023) about curriculum reform guided by critical thinking skills as learning objectives. This is because guiding students with a less stable foundation of critical thinking may not be able to improve students' critical thinking skills. This principle refers to the alignment of teaching methods and assessment with learning goals or objectives. In this case, critical thinking skills are embedded in the curriculum as one of the educational outcomes that must be demonstrated by students, and these skills are aligned with problem-based learning and assessment as teaching methods. Batlolona & Souisa (2020) have identified problem-based learning as a good example of a constructively aligned teaching system. This view is in line with Kek & Huijser (2011) that PBL is a powerful pedagogical approach because it explicitly and actively involves students in the learning and teaching system, characterized by a reiterative and reflective cycle in studying specific domain knowledge and doing thinking itself. At the same time, students are guided and facilitated by problem-based learning teachers, who model critical thinking skills in the acquisition of specific domain knowledge. Early evidence from the field of student learning and teaching approaches also shows that student-centered teaching approaches have a high impact factor that influences higher-order thinking skills, in the form of deep learning and independent learning. Evidence also shows that students in student-centered problem-based learning environments demonstrate higher-order thinking abilities and learning skills (Brodie, 2009). Overall, this

brings us back to the question of what makes problem-based learning as a pedagogy suitable for teaching critical thinking skills.

The results of this study are in line with the findings of Darmawati & Mustadi, (2023), tentang "the effect of problem-based learning on the critical thinking skills of elementary school students", which found that the implementation of problem-based learning positively and significantly influences the critical thinking skills of fifth-grade elementary school students in science subjects. This is because problem-based learning models emphasize a student-centered learning process aimed at developing problem-solving skills through independent learning (Ali, 2019). Additionally, a similar study by Dakabesi & Luoise, (2019) found that students who learn with problem-based learning models have better critical thinking skills than those who learn using conventional models. Furthermore, according to Razak et al., (2022), problem-based learning is a primary approach used in teaching students to develop various skills, such as critical and creative thinking, problem-solving, cooperation, effective communication, and global literacy. The critical thinking abilities of students were measured using five indicators from Ennis (2011), namely: 1) providing simple explanations (8.5%), 2) building basic skills (20%), 3) concluding (40%), 4) providing further explanations (45.7%), and 5) regulating strategies and tactics (20%). The research results indicate that the implementation of Problem-Based Learning (PBL) on human respiratory system material enhances students' critical thinking abilities. Students become more active, independent, motivated, confident, and engaged in the learning process, and are able to collaborate with teachers to find and solve problems. This study strengthens the evidence that PBL is effective in developing critical thinking, consistent with the findings of Benítez-Chavira et al. (2025) , who reported that PBL significantly improved critical thinking and problem-solving skills among nursing students in various educational settings. PBL not only provides theoretical knowledge but also enhances the cognitive processes required for clinical decision-making. A study also showed that the PBL Teaching Group demonstrated significantly better post-test scores compared to the Traditional Teaching Group ($P<0.05$). Furthermore, the PBL Teaching Group showed significantly higher post-assessment scores in health education ability ($P<0.05$), self-directed learning ability ($P<0.05$), and critical thinking ability ($P<0.05$) (Xue et al., 2025). In Pakistan, a study highlighted that integrating case-based and problem-oriented strategies in nursing education resulted in measurable improvements in students' ability to interpret clinical scenarios and make informed decisions (Liaqat & Shafi, 2025).

Building the capacity of elementary school students to face future challenges through PBL in science education in the era of globalization and rapid technological advancements. In the era of globalization and rapid technological advancements, science education in elementary schools plays a crucial role in preparing students to face future challenges. One effective approach to achieve this goal is PBL. PBL is a learning approach that focuses on providing students with real and complex problems, enabling them to learn actively, critically, and creatively. PBL helps students develop problem-solving skills, which are essential for facing future challenges. By using PBL, students can understand science concepts better, as they learn through direct and contextual experiences. PBL also encourages students to think critically and creatively in seeking solutions to problems, enabling them to develop better thinking skills. Moreover, PBL involves students in group work, allowing them to develop effective collaboration and communication skills. PBL makes learning more engaging and relevant to daily life, increasing student motivation and participation. Therefore, the implementation of PBL in science education for elementary school students is crucial in preparing them to face future challenges. PBL helps students develop the ability to tackle complex and unpredictable problems, which are essential skills for future success. Hence, PBL can be an effective approach to improving the quality of science education in elementary schools. PBL is a student-centered and outcome-based approach that has been proven to enhance the quality of learning across various disciplines and academic levels. PBL is described as a teaching strategy that focuses on a process that uses small groups to solve well-integrated clinical problems. Unlike traditional learning, which heavily relies on lectures and limited self-study, PBL encourages active problem-solving and collaboration among students (Ge et al., 2025). PBL has been hailed as "the most significant innovation in education for the professions in years," a testament to its transformative impact on the education sector (Ngereja et al., 2020). Furthermore, experienced PBL teachers play a vital role in helping nursing students build a strong knowledge base by promptly addressing their questions. Additionally, recent trends in PBL teaching involve using cases as a guide for learning in specific content areas (Wei et al., 2024).

5. Conclusion and suggestions

The critical thinking skills of students in the control group, which used traditional learning models, were still in the very low category, both before (pretest) and after learning (posttest). The changes that occurred were more of a shift in indicators that emerged, rather than a significant increase in the number and quality of achievements. Therefore, traditional learning models were proven to be less effective in developing students' critical thinking skills, as they did not provide ample opportunities for exploration, discussion, and problem-solving that promote higher-order thinking. The results of the pretest-posttest showed that the problem-based learning (PBL) model was effective in developing

students' critical thinking skills. The improvement in critical thinking occurred because the PBL model placed students at the center of learning by presenting them with real-world problems to analyze and solve. This process engaged students actively in identifying problems, seeking information, discussing, and drawing conclusions. These activities directly trained analytical skills, logical reasoning, and arguments, so that each indicator of critical thinking developed better. In other words, PBL not only conveyed material but also provided a learning experience that encouraged students to think at a higher level.

The application of the problem-based learning model was able to influence students' critical thinking on the human respiratory system material for fifth-grade students at SD Negeri 87 Ambon. This can be seen from the hypothesis test using the Ancova test, which showed Fcount > Ftable, resulting in 11.414 > 2.74 and a significance of 0.001 < 0.05, indicating that Ho was rejected and Ha was accepted. So, we can concluded that the learning model has a significant effect on students' critical thinking skills. The results of the LSD test of critical thinking with learning models shows that students' critical thinking skills taught using the PBL learning model differ significantly from those taught using conventional learning models. Based on the research conducted, it is suggested that every school can provide more effective support for the implementation of problem-based learning (PBL) in elementary schools, considering its effectiveness in improving student learning outcomes. Additionally, schools are expected to provide facilities such as training and mentoring for teachers to optimize the implementation of PBL according to the characteristics of students. For further research, it is suggested to conduct a more in-depth study on the effectiveness of PBL in various subjects and analyze the factors that influence the success of its implementation, such as parental involvement, availability of learning resources, and students' learning styles.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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