



The effect of problem-based learning model in science process skills on respiratory system materials

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ABSTRACT

This research aims to determine the effect of problem-based learning (PBL) learning model on the science process skills (SPS) of grade XI students on respiratory system material. This research used quantitative method with pre-experimental design. Biology learning requires student-centered learning to improve students' science process skills. However, students are rarely involved in teaching and learning activities. The low level of participation of students in biology learning causes the science process skills of students to be less emphasized. The research was conducted by applying the PBL model to class XI.7 at SMAN 1 Palembang with respiratory system learning material. The instruments used included pre-test and post-test SPS tests, as well as a questionnaire sheet for students' responses to learning using PBL. Data analysis was done by normality test, paired t-test, effect size test, and N-gain test. The results showed that there was a significant effect on students' SPS with learning using the PBL model. The PBL model has a positive influence in improving the SPS aspects of observing, classifying, concluding, predicting, and communicating. This is supported by the results of filling out a questionnaire of students' responses to learning using the PBL model as a whole giving a very good response to PBL. This research can be further developed by using further research designs, such as research using a control class to determine the comparison of the effectiveness of PBL models with other learning models.

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INTRODUCTION

The curriculum acts as a reference in learning at school (Gumilar et al., 2023). Currently, education in Indonesia implements the Merdeka Curriculum as a foundation by emphasizing learning based on the interests and talents of students who provide freedom of exploration. In the Merdeka Curriculum, there are learning outcomes that must be achieved with two main elements, namely science understanding and process skills, which in carrying out learning, the process skills element is a method used to obtain science understanding so that these two elements are in one whole (BSKAP, 2024). There are three main aspects in learning Biology, namely process, product, and scientific attitude (Saputri, 2022). Biology as a science requires students to think critically through minds-on, hands-on, and hearts-on approaches in learning activities (Subali, 2010). However, in reality, the science process skills (SPS) of students are still low due to the lack of active involvement in learning (Rahmasiwi et al., 2015). SPS is important in the process of implementing the learning process. SPS in students can spur students in solving problems found in everyday life (Saputri, 2022).

SPS is an important skill in understanding and applying science concepts in everyday life. SPS is divided into two, namely basic SPS which includes observing, classifying, inferring, and predicting, and integrated SPS including designing experiments, interpreting data, and making conclusions (Novitasari & Aminatun, 2021; Kusuma & Rusmansyah, 2021). Along with technological developments, SPS is an essential skill for students in facing the challenges of the 21st century (Triani et al., 2023). SPS (such as observing, classifying, predicting, and communicating) are basic skills needed to understand and apply science concepts in everyday life. SPS is the foundation for developing 21st-century skills because it involves scientific activities that are relevant to the needs of the modern era, such as science literacy, technology adaptation, and collaboration. Therefore, a learning model that can optimally improve SPS is needed.

Biology learning requires student-centered learning to improve students' science process skills. However, students are rarely involved in teaching and learning activities. The low level of participation of students in biology learning causes the science process skills of students to be less emphasized. One of the appropriate learning models is Problem-Based Learning (PBL). PBL is more effective than conventional models on science process skills because PBL models help students understand concepts more deeply (Tosun & Taskesenligil, 2013). The PBL model emphasizes solving real problems that can train students to think critically and scientifically (Wahyudi et al., 2015). PBL is also proven to improve students' higher-order thinking skills, concept understanding, and communication skills (Agnesa & Rahmadana, 2022; Ilhami et al., 2023). The PBL model has five syntaxes, namely focusing on the problems faced by students, organizing learning activities for students, providing guidance in individual and group research, returning and presenting work, and analyzing and evaluating the problem-solving process (Ariyana et al., 2018).

There are several materials in Phase F high school biology that are considered difficult, one of which is respiratory system material. Respiratory system material in Phase F high school biology discusses the relationship between organ structure and its function in responding to external stimuli (BSKAP, 2024). This material is often considered difficult because students cannot directly observe human respiratory organs (Myanda et al., 2020). However, the concepts in this material are also interesting because they are directly related to everyday life with many concepts, such as the process of the respiratory system in humans (Çimer, 2012) which is certainly always experienced as a living being that breathes. Therefore, learning with PBL-based respiratory system material is expected to improve concept understanding while increasing students' SPS.

PBL model involves students actively in understanding the concepts and principles of a material that helps students develop thinking and problem-solving skills (Supiandi & Julung, 2016). Research on SPS conducted by (Ajoke & Joe, 2012; Nwagbo & Chukelu, 2008) shows the influence of the application of learning models in improving students' SPS with models that involve students in active learning. Previous research shows that the application of PBL has a positive influence on students' SPS because students are accustomed to discussing and presenting to foster confidence in communicating (Janah et al., 2018). The importance of explicit teaching models and repeated practice to help students' develop SPS can be widely applied (Auntoh & Woolnough, 1994). Previous research highlighted the effect of PBL on SPS in general which has not focused on specific materials or curriculum. Therefore, this research fills the gap by applying PBL to repository system materials in class XI in Merdeka Curriculum that emphasizes independent exploration of students. This is relevant because repository system material is considered difficult by students (Myanda et al., 2020), so it needs a special approach such as PBL to

improve understanding and SPS. This research aims to determine the effect of the problem-based learning (PBL) learning model on the science process skills (SPS) of grade XI students on the respiratory system.

METHODS

Research Design

Data collection was carried out at SMAN 1 Palembang using class XI.7 as much as 1 meeting for filling the pre-test, 4 learning meetings, and 1 meeting for filling the post-test and questionnaire in the odd semester of the 2024/2025 school year. This type of research is quantitative research.

This type of research is quantitative research using an experimental research design, namely pre-experimental, which is an experimental method that has external variables that affect the formation of independent variables. The design form in this study is One-Group Pretest-Posttest Design which has no control group and there is a pretest before treatment and a posttest after treatment to determine the treatment results more accurately (Sugiyono, 2022).

Population and Samples

This study used all students of class XI which amounted to 12 classes at SMAN 1 Palembang for the population. The research sample was selected using Random Sampling technique. The random sampling technique used in this research was a simple random sampling method, where all students of class XI at SMAN 1 Palembang (population of 12 classes) had the same opportunity to be selected as a sample. The research sample was determined randomly without regard to certain strata, and class XI.7 consisting of 35 students was selected. This technique of the population and to reduce bias in the selection of respondents.

Instrument

Data collection techniques in this study used tests in the form of pre-test, post-test, and questionnaire. The test was applied twice to students to obtain data related to students' science process skills objectively in the form of multiple choices. The question consists of 25 items that cover aspects of students' science process skills with a total maximum score of 100. The questions are applied to the pre-test (before the learning model is applied) and post-test (after the learning model is applied).

Questionnaires are used to determine students' responses to learning by using the Problem Based Learning model applied to Respiratory System material to class XI students. The questionnaire uses a Likert scale with five scales, namely "Strongly Agree", "Agree", "Undecided", "Disagree", and "Disagree", then given to students at the final meeting of the material to collect data in the form of students' responses to the learning model applied.

Procedure

This study used quantitative methods, namely pre-experimental with a one group pretest post-test design where there is only one group without a control group. The population of this study was all students of class XI at SMAN 1 Palembang, which consisted of 12 classes XI with the research sample selected using random sampling, namely class XI.7 which amounted to 35 students. The research instruments included a multiple-choice SPS test of 25 items to measure students' SPS through pre-test and post-test, and a questionnaire with a Likert scale to determine students' responses to learning using the PBL model on respiratory system material. Data collection was carried out with 1 meeting for filling in the pre-test, 4 learning meetings, and 1 meeting to filling in the post-test and questionnaire in the odd semester of the 2024/2025 school years.

The research procedure consists of three stages. The preparation stage includes sample selection, preparation and validation of teaching modules and LKPD, and preparation of research instruments. The implementation stage begins with a pre-test, followed by the application of the PBL model in learning, and students are divide into groups to solve together problems related to the material being taught. After the learning is complete, a post-test is conducted and a questionnaire is filled out by students. The completion stage is data processing and analysis using the normality test, paired t test, effect size test, and N-gain test, while the lift data is analyzed directly using Ms. Excel. The analysis aims to determine the effect of the PBL model on students' SPS.

Data Analysis Techniques

The research data were analyzed using the paired T test. Before conducting the paired T test, a normality test was conducted to determine the data obtained from the population with normal distribution or normal distribution. The normality test uses Shapiro-Wilk which is said to be normal if the data shows > 0.05 . Paired T test is conducted to test the hypothesis of significant or insignificant

effect. Then, the effect size test was conducted to determine how influential PBL was on SPS. The effect is said to be low if ≤ 0.20 and said to be high if ≥ 0.80 (Cohen, 1988). The magnitude of the increase in learning outcomes (SPS) of students is calculated by the N-Gain test to measure what happens before and after the application of PBL to show the extent to which students master the learning provided (Hake, 1998). The improvement of students' mastery of learning is grouped into five categories, namely: high ($0.70 \leq g \leq 1.00$), medium ($0.30 \leq g \leq 0.70$), low ($0.00 < g < 0.30$), no improvement ($g = 0.00$), and a decrease ($-1.00 \leq g < 0.00$).

RESULTS AND DISCUSSION

A. Data Analysis of Science Process Skills Test Results of Students

This test aims to measure the ability of students' process skills before and after being treated with the Problem-Based Learning model on respiratory system material. The SPS aspects that appear in this learning are observing, classifying, concluding, predicting, and communicating. The average score of students during the pre-test and post-test can be seen in the [Table 1](#).

Table 1

Pre-test and Post-test Score of Students

No.	Value Predicate	Pre-test (%)	Post-test (%)
1.	Very Good	15.00	91.00
2.	Good	42.00	9.00
3.	Simply	18.00	0.00
4.	Less	21.00	0.00
5.	Very Less	3.00	0.00

[Table 1](#) shows that the average post-test score of Students' increased compared to the pre-test average. In the pre-test, excellent scores were only achieved by 5 Students', while in the post-test, 33 students could achieve excellent scores.

B. Normality Test

The normality test is carried out on the data of students' test results to find out whether the data is normally distributed or not. The normality test uses the Shapiro-Wilk normality test type because the data is 33 less than 50. The normality test results can be seen in [Table 2](#).

Table 2

Normality Test Results of Science Process Skills Pre-test

	Statistic	Df	Sig
Pre-test results	0,942	33	0,078

Based on the results presented in [Table 2](#), it shows that the pre-test data is normally distributed with a significance number of $0.078 > 0.05$.

C. Paired T-Test

Paired T-test test was conducted using the data of students' SPS test results. The results of the paired T-test can be seen in [Table 3](#) below.

Table 3

Paired T-Test of Science Process Skills

Pre-test & Post-test Results	Mean	Std. Deviation	Std. Error Mean	T	df	Sig (2-tailed)
	-30,788	19,480	3,391	-9,079	33	0,000

[Table 3](#) shows the significance value is $0.000 < 0.05$. This shows that the application of the PBL model has a significant effect on students' SPS.

D. Effect Size Test

Cohen's d effect size test uses data from pre-test and post-test results to determine how much influence the application of the PBL model has on students' SPS. The results of the effect size test can be seen in [Table 4](#).

Table 4
Effect Size Test Results PBL Model on SPS

	Mean	Std. Deviation	n
Pre-test	60.61	21.38	33.00
Post-test	91.39	8.43	33.00
Cohen's d		1.89	

[Table 4](#) shows that the effect size value of the students' SPS test results with the application of the PBL model is 1.89, which means that learning with the PBL model has a high influence on students' SPS.

E. N-Gain Test

The N-Gain was conducted with the pre-test and post-test data of students' SPS. N-Gain test data from students' test results can be seen in [Table 5](#).

Table 5
Interpretation Results of N-Gain Test of SPS Test for Students

Interpretation	Amount (%)
High	67.00
Medium	30.00
Low	0.00
No change occurred	3.00
There is a decrease	0.00

The data shows that there are 67.00% of students who have an N-Gain score with a high interpretation, 30% of students with a medium interpretation, and 3.00% of students who do not change. N-Gain data on aspects of science process skills can be seen in [Table 6](#).

Table 6
N-Gain of Science Process Skills Aspect

Aspects	Pre-test	Post-test	N-Gain	Interpretation
Observing	68.93	92.42	0.76	High
Categorize	64.39	94.70	0.85	High
Summarize	53.24	90.48	0.80	High
Predict	61.21	87.88	0.69	Medium
Communicate	60.60	92.73	0.82	High

[Table 6](#) shows that the N-Gain value of the SPS aspect has a high category in the indicators of inferring, classifying, communicating, and observing which is >0.70 and the predicting aspect is in the medium category.

F. Data Analysis Results of Learner Response Questionnaire

Students' responses to learning using the PBL model were obtained from filling out the response questionnaire sheet. The response questionnaire instrument uses a questionnaire sheet from research (Nurshinta, 2018) which is modified according to the learning applied using a Likert scale. The questionnaire was given after the learning and post-test was completed. The questionnaire data can be seen in [Table 7](#).

Table 7

Percentage of Students' Response to Learning with PBL in each Statement

Category	SA (%)	A (%)	NR (%)	DA (%)	SDA (%)
Students' perception of PBL	61.76	38.23	0.00	0.00	0.00
	50.00	50.00	0.00	0.00	0.00
	58.82	41.17	0.00	0.00	0.00
Understanding and mastery of the material	52.49	47.05	0.00	0.00	0.00
	55.88	44.11	0.00	0.00	0.00
	58.82	38.23	2.94	0.00	0.00
Effect of PBL on SPS	55.88	41.17	2.49	0.00	0.00
	52.94	47.58	0.00	0.00	0.00
Learning method preference	61.76	32.25	5.88	0.00	0.00
	52.94	47.05	0.00	0.00	0.00
Learning interaction and engagement	61.76	38.23	0.00	0.00	0.00
	58.82	38.23	2.94	0.00	0.00
	52.94	47.05	0.00	0.00	0.00

Note: SA (Strongly Agree), A (Agree), NR (Not Really), DA (Disagree), SDA (Strongly Disagree)

Table 7 shows that overall the Students' gave a very good response to learning with PBL model. The total percentage of students' responses to learning with PBL can be seen in Table 8.

Table 8.

Total Percentage of Students' Response to Learning with PBL

Predicate	Total (%)
Very Less	0.00
Less	0.00
Simply	0.00
Good	18.00
Very Good	82.00

Table 8 shows that students' responses to learning with the PBL model are dominant in the very good category with a total of 82% and good as much as 18%. Learning is carried out with this PBL model using 5 syntaxes, namely focusing on the problems faced by students, organizing learning activities for students, providing guidance in group research, guiding to develop and present work results, and analyzing and evaluating the results of problem solving that can develop SPS. The application of PBL can increase curiosity, pleasure in answering problems, and can improve students' communication skills because in the PBL model students work in groups and require communication, problem solving, and collaboration skills (Anwar et al., 2021). Giving a problem first related to the material will raise the curiosity of students so that it can improve the aspect of observing, giving a problem sheet can make students estimate the results that can improve the aspect of predicting, conducting research or experiments so that students get data information that can improve the aspect of interpreting or concluding, giving worksheets to direct students to find concepts can improve the aspect of classifying, conducting group discussions and presenting results can improve the communication aspect (Hasanah & Utami, 2017). The stages incorporated in the PBL model are able to help students improve their creative thinking skills, and encourage teachers to continue to train students in logical and analytical thinking to solve problems in accordance with the directions taught (Khoiriyah & Husamah, 2018). The five syntaxes in the implementation of PBL show that the role of students in this model is very dominant because all information related to problem solving is directed to be done independently or in groups with the teacher's role as a facilitator, providing feedback, and reinforcing it when needed (Fadilla et al., 2021).

The application of PBL as a learning tool relies on the use of everyday cases and problems where Students' have the opportunity to find new knowledge to their continuing knowledge to solve problems that make Students' participate in an active process to create innovative solutions to problems through their experiences (Birgili, 2015). The PBL provides a meaningful learning experience for students because it encourages them to play an active role in understanding and developing knowledge independently (Esema et al., 2024). Learning is carried out through this PBL model by applying 5 syntaxes, namely focusing on the problems faced by students, organizing learning for students,

providing guidance in group research, guiding to present and develop work results, as well as analyzing and assessing the results of solving problems that can develop SPS. The syntax of the PBL model, according to (Ariyana et al., 2018) is to focus on the problems faced by students, organize learning activities for students, provide direction in individual and group research, support the development and presentation of work results, and assist in evaluating and analyzing the problem-solving process. PBL syntax which begins with the presentation of problems relevant to the material, can raise the curiosity of students so that it can improve the aspect of observing, providing problem sheets can make students estimate results that can improve the aspect of predicting, conducting research or experiments so that students get data information that can improve the aspect of interpreting or concluding, providing worksheets to direct student to find concepts can improve the aspect of classifying, conducting group discussions and presenting results can improve the aspect of communicating (Hasanah et al., 2017). The PBL model can improve students' SPS because learning can facilitate science process skills through of its learning syntax (Hartati et al., 2022).

PBL encourages the development of professional skills such as critical thinking, independent learning, cooperation, and communication (Carrió et al., 2011). The PBL model can develop students' critical thinking skills in solving problems given by the teacher, and can improve students' learning outcomes in general (Ningrum et al., 2023). PBL, which is applied through five stages, namely organizing students to learn, guiding group investigations, developing and presenting results, and analyzing and evaluating the problem-solving process is an effective model for improving students' critical thinking skills in learning biology (Jannah & Saifuddin, 2024). One of the high-level thinking skills is critical thinking, which is a key competency that must be possessed to solve problems and to be able to interpret, analyze, and provide alternative solutions to problems (Nugraha et al., 2017). The problem-based learning model can improve students' problem-solving skills by providing opportunities for students to develop problem-solving abilities through learning that explores problem-solving skills and critical thinking skills with the characteristics of the model including students working together in groups to solve problems presented by the teacher (Komala et al., 2021). In addition, this model also increases students' involvement in learning, both individually and in groups (Agustina et al., 2025). During learning that is applied PBL, students' activities during learning increase, especially in group involvement and cooperation (Priilyta et al., 2016). SPS is the skill of processing information from the learning provided to be observed, categorized, concluded, predicted, applied, planned, and evaluated so that with SPS, students can also think critically (Putri et al., 2022). Science process skills and critical thinking skills of students are interrelated because developing SPS requires higher-level thinking which is inseparable from critical thinking. The PBL model provides opportunities for students to develop science process skills during learning which if SPS is good it will produce good learning outcomes as well (Janah et al., 2018). The PBL model can affect students' SPS because learning is oriented towards direct involvement of students in problem solving which makes students think at a high level to solve problems. Problem solving increases the curiosity of Students' to find solutions to problems which in the process also develops science process skills including observing, classifying, concluding, predicting, and communicating.

CONCLUSION

Based on the results of the study, it can be concluded that the Problem Based Learning (PBL) model has a significant effect on improving the Science Process Skills (SPS) of grade XI students on respiratory system material. This research examined the effectiveness of the PBL model in enhancing the SPS of Grade XI students on respiratory system material. Using a pre-experimental design, the research demonstrated that PBL significantly improved students' SPS, as evidenced by the post-test results. The model fostered active engagement, critical thinking, and collaborative problem-solving, aligning with the goals of the *Merdeka Curriculum*. Students also responded positively to PBL, indicating its suitability for biology education. These findings underscore PBL's potential as a valuable approach to developing essential 21st-century skills in science learning.

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aspects of SPS can appear with one material alone, further research can examine the development of PBL models that can integrate all aspects of SPS to be more optimally developed.

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