Bioeduca: Journal of Biology Education
http://journal.walisongo.ac.id/index.php/bioeduca
ISSN 2714-8009 (print), 2715-7490 (online)

Volume 7, Nomor 1, Tahun 2025
Hal. 01 – 14

Unveiling the Impact of Problem-Based Learning on Students' Science Process Skills and Cognitive Outcomes

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Article Information
Submited: 23 – 09 – 2024
Accepted: 26 – 03 – 2025
Published: 31 – 03 – 2025

Publisher
Program Studi Pendidikan Biologi, Fakultas Sains dan Teknologi, UIN Walisongo Semarang

ABSTRAK

Pembelajaran berbasis masalah (PBL) adalah pendekatan berbasis masalah dunia nyata yang melatih siswa untuk berpikir ilmiah, melakukan investigasi, dan membangun pengetahuan secara logis berdasarkan bukti. Melalui pengalaman empiris dan pemecahan masalah yang kompleks, siswa dapat meningkatkan keterampilan proses sains dan hasil belajar mereka. Penelitian ini bertujuan: 1) mengetahui pengaruh model pembelajaran PBL terhadap keterampilan proses sains dan hasil belajar kognitif; 2) mengetahui hubungan antara keterampilan proses sains dan hasil belajar kognitif siswa di MAN 1 Lombok Barat. Metode penelitian ini merupakan penelitian kuantitatif tipe eksperimen semu dengan desain penelitian *the none-equivalent postest control group design*. Sampel dalam penelitian ini adalah 50 siswa kelas X. Instrumen penelitian ini menggunakan lembar observasi dan tes. Data dianalisis menggunakan manova dan regresi linier sederhana. Penelitian menunjukkan bahwa PBL berpengaruh positif dan signifikan terhadap keterampilan proses sains dan hasil belajar kognitif siswa. Selain itu keterampilan proses sains memiliki peran mediasi antara PBL dan hasil belajar kognitif. PBL akan meningkatkan keterampilan proses sains, sehingga berdampak terhadap hasil belajar siswa.
Kata kunci: Hasil Belajar Kognitif; Keterampilan Proses Sains; PBL.

ABSTRACT

Problem-based learning (PBL) is an approach based on real-world problems that trains students to think scientifically, conduct investigations, and construct knowledge logically based on evidence. Through empirical experiences and complex problem-solving, students can improve their SPS and learning outcomes. This study aims: 1) to determine the effect of a PBL model on SPS and cognitive learning outcomes; 2) to determine the relationship between SPS and cognitive learning outcomes among students at MAN 1 West Lombok. This research method is a quantitative type of quasi-experimental research with a non-equivalent posttest control group design. The sample was 50 students in class X. The research instrument used observation sheets and tests. The data were analyzed using Manova and simple linear regression. Research has shown that PBL has a positive and significant effect on students' SPS and cognitive learning outcomes. Furthermore, SPS play a mediating role between PBL and cognitive learning outcomes. PBL enhances students' SPS, which in turn positively influence their learning outcomes.
***Keywords**: Cognitive Learning Outcomes, PBL, SPS.*

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INTRODUCTION

Science process skills (SPS) are essential in the era of Society 5.0, which is characterized by rapid change and complex challenges (Saputro et al., 2020). In this era, information is abundantly available, and students must develop the ability to filter, evaluate, and analyze information critically (Arsanti et al., 2020). Students who do not master SPS often struggle to comprehend scientific concepts. Conversely, SPS such as observing, questioning, designing experiments, and collecting and analyzing data enable students to deepen their understanding of scientific ideas (Sholahuddin et al., 2020; Sari et al., 2020). Without these skills, students may find it difficult to understand causal relationships between variables in experiments or to connect theory with empirical observations (Rahayu, 2019).

SPS are positively related to students' cognitive learning outcomes (Ilma et al., 2020; Nirmalasari, 2018). SPS encompasses cognitive, affective, and psychomotor abilities that allow students to understand, analyze, and evaluate scientific concepts and apply them in real-life contexts (Khairi & Abdullah, 2020). Cognitive learning outcomes, in turn, reflect students' mastery of subject matter and their ability to apply it in everyday situations (Atmaja, 2021). Mastery of SPS can enhance students' understanding, critical thinking, and motivation to learn science, thereby contributing to better achievement and comprehension of scientific concepts (Sarjono & Hariyadi, 2021).

Cognitive learning outcomes are the primary goals of instruction, representing students' achievement after completing learning activities (Rao, 2020; Surya, 2018). To achieve these goals, teachers must apply effective strategies, appropriate instructional approaches, methods, and media that align with the learning material (Murtado, 2023; Sofi-Karim et al., 2023). Learning methods should also promote active student participation, ensuring that students are directly involved in the learning process (Purnamasari, 2018).

A preliminary study conducted at MAN 1 West Lombok on May 4, 2023, revealed that teachers had implemented various biology learning methods. However, these learning activities had not yet optimized students' cognitive learning outcomes in biology. Students' abilities to ask questions, observe, design experiments, and analyze data remained limited, indicating that their SPS had not developed optimally. The lack of these skills is presumed to negatively affect students' cognitive learning outcomes at MAN 1 West Lombok.

One of the problem-solving learning strategies that can enhance students' SPS and cognitive learning outcomes is Problem-Based Learning (PBL) (Lawi, 2020; Rauf, 2023). This approach encourages students to engage interactively in solving complex, real-world problems (Astuti, 2019). PBL positions students as active learners who address authentic problems using their prior knowledge and experiences (Rosmala, 2021). Therefore, PBL can serve as an effective model for developing students' SPS and improving learning outcomes in science education (Putri & Ermawati, 2021).

Previous studies have shown that PBL can improve SPS and learning outcomes (Sudarmanto, 2021; Rifai, 2022; Sellmeijer et al., 2018; Sarah et al., 2018; Fitria, 2019; Akbar, 2023; Budianto, 2021; Nurrita, 2018; Adi, 2022). However, the extent to which PBL correlates with cognitive learning outcomes has not been widely investigated. Therefore, this study aims not only to determine the effect of the PBL model on SPS and cognitive learning outcomes but also to examine the correlation between these two variables.

METHOD

This study employed a quantitative approach and a quasi-experimental design. The experimental class received treatment using the Problem-Based Learning (PBL) model, while the control class underwent conventional instruction (without treatment). The PBL syntax used in this study refers to Elaine (2017). The research was conducted at MAN 1 West Lombok with Grade X students during the odd semester of the 2023–2024 academic year (January–February).

Table 1. Syntax PBL (Elaine, 2017)

No.	Syntax	Description
1	Student Orientation to the Problem	Introducing students to the problem and motivating them to engage in the learning process.
2	Organizing Students for Learning	Structuring students into groups and clarifying learning objectives, roles, and tasks.
3	Guiding Individual or Group Investigations	Facilitating students as they gather information, explore concepts, and develop potential solutions.
4	Developing and Presenting Work	Supporting students in constructing, organizing, and presenting their findings or solutions.
5	Analyzing and Evaluating the Problem-Solving Process and Results	Engaging students in reflection and assessment of their learning outcomes and the effectiveness of the problem-solving process.

The population consisted of all Grade X students at MAN 1 West Lombok in the 2023–2024 academic year. The sample of this study comprised students from classes X-A and X-B. The focus of this research was to examine students' SPS and learning outcomes in the topic of biodiversity within the biology subject. The samples were selected using a clustered random sampling technique. In this study, class X IPA A served as the control group, while class X IPA B served as the experimental group.

Table 2. Sample

Class	Total
IPA A	25
IPA B	25
Total	50

The instruments used in this study were observation sheets and tests. The SPS observed included (1) observing, (2) classifying, (3) interpreting, (4) predicting, (5) asking questions, (6) formulating hypotheses, (7) designing experiments, (8) applying concepts, and (9) communicating. The test instrument was used to measure

students' cognitive learning outcomes, which were aligned with the parameters for assessing cognitive achievement. The research test consisted of a written post-test designed to measure students' learning outcomes after the implementation of the Problem-Based Learning (PBL) model. The test was in the form of an essay comprising eight questions. Prior to use, the test was examined for validity and reliability.

Assumption tests for data analysis included homogeneity, normality, and linearity. A multivariate analysis of variance (MANOVA) was employed to compare the means of the control and experimental groups. In addition, simple regression analysis was used to determine the relationship between SPS (X) and cognitive learning outcomes (Y). All analyses were conducted using SPSS software.

RESULTS AND DISCUSSION

Results

This study was conducted to improve students' SPS and cognitive learning outcomes in the classroom in science subjects using the problem-based learning model on the biodiversity material for class X MAN 1 West Lombok, academic year 2023-2024. An analysis of SPS and students' cognitive learning outcomes is presented in Table 1.

Table 3. Descriptive Analysis of SPS and Students' Cognitive Learning Outcomes

Variable	n	Average									
		Control					Experiment				
		Mean	SD	Min	Maks	%	Mean	SD	Min	Maks	%
SPS	25	75	7,52	61	89	75	79	9,15	67	92	79
Cognitive Learning Outcomes	25	80,12	8,15	62	91	88	81,16	9,15	59	94	88

According to Table 1, the average value of SPS in the experimental class is higher than that in the control class (79 > 75). This shows that there is potential that the treatment in the experimental group may have a positive impact on SPS compared to the control group. The science process skill criteria of 79% means it is included in the criteria (good).

The average value of cognitive learning outcomes in the experimental class is higher than in the control class (81.16 > 80.12). It can be concluded that the average learning outcomes of the experimental class are higher than those of the control class. While the cognitive learning outcome criteria of 88 means it is included in the criteria (good), Furthermore, the comparison of the average SPS and students' cognitive learning outcomes based on the indicators is shown in the graph in Figure 1 below.

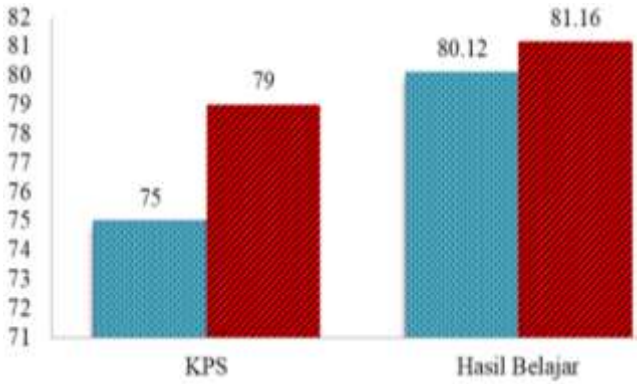

Figure 1. Comparison of Variables Between Groups. Blue as Control Group, Red as a Treatment Group.

Based on Figure 1, it is known that the average value of SPS is 79 > 75. While the average value of students' cognitive learning outcomes is 81.16 > 80.12. In conclusion, SPS and students' cognitive learning outcomes in the experimental class are higher than in the control class. The normality analysis of SPS and students' cognitive learning outcomes is presented in Table 2.

Table 4. Normality Test of SPS

Variable	Class	Kolmogorov-Smirnova			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
SPS	Control	0,123	25	0,200*	0,980	25	0,881*
	Experiment	0,132	25	0,200*	0,945	25	0,195*
Cognitive Learning Outcomes	Control	0,143	25	0,200*	0,928	25	0,079*
	Experiment	0,138	25	0,200*	0,948	25	0,228*

Based on table 2, the significance value of students' SPS is 0.200 > 0.05, so it can be concluded that the data is normally distributed and can be continued with simple regression and manova tests. The significance value of students' cognitive learning outcomes is 0.200 > 0.05, so it can be concluded that the data is normally distributed. The analysis of the homogeneity of SPS and students' cognitive learning outcomes is presented in Table 3 below.

Table 5. Homogeneity Test of SPS and Cognitive Learning Outcomes

Variable	Levene Statistic	df1	df2	Sig.
SPS	0,728	1	48	0,398*
Cognitive Learning Outcomes	0,293	1	48	0,591*

Based on table 3, the significance value of SPS is 0.398 > 0.05, while the significance value of learning outcomes is 0.591 > 0.05. So it can be concluded that the data is homogeneously distributed and can be continued with simple regression and Manova tests. A linearity analysis of SPS and learning outcomes is presented in Table 4 below.

Tabel 6, Liniarity Test

ANOVA Table

			Sum of Squares	df	Mean Square	F	Sig.
SPS * Cognitive Learning Outcomes	Between Groups	(Combined)	432.383	11	39.308	0,551	0,836
		Linearity	218.280	1	218.280	3.059	0,104
		Deviation from Linearity	214.104	10	21.410	0,300	0,968
	Within Groups		927.617	13	71.355		
	Total		1360.000	24			

Table 4 shows the results of the linearity test obtained from the deviation from the linearity row, namely Fhit = 0.300, with a p-value of 0.968 > 0.05. This means that the regression equation of SPS (y) on students' cognitive learning outcomes (x) is a linear line. An analysis of the influence of the problem-based learning model on SPS and students' cognitive learning outcomes is presented in Table 5 below.

Table 7. Results of Multivariate MANOVA Tests

Effect	Value	F	Hypothesis df	Error df	Sig.
PBL	Pillai's Trace	0,130	3.509b	2.000	0,038*
	Wilks' Lambda	0,870	3.509b	2.000	0,038*
	Hotelling's Trace	0,149	3.509b	2.000	0,038*
	Roy's Largest Root	0,149	3.509b	2.000	0,038*

In table 5, the significance value is 0.038 <0.05, meaning that there is an influence of SPS on students' academic achievement. According to the criteria Ho (reject) and Ha (accept), problem-based learning (PBL) on SPS and students' cognitive learning outcomes has a significant effect. And the results of the Manova test of the between-subjects effects table are presented in the Table 6 below.

Table 8. Manova Test Results of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
PBL	Hasil Belajar	292.820	1	292.82	5.28	0,026
	KPS	81.920	1	81.920	1.16	0,286

It can be seen in Table 6 that the influence of problem-based learning on students' cognitive learning outcomes is 0.0260 <0.05 and the significance value of problem-based learning on students' SPS is 0.2860 > 0.05. In conclusion, the problem-based learning model has a significant influence on students' cognitive learning outcomes, while problem-based learning does not have a significant influence on students' SPS. An analysis of the results of a simple regression test of SPS on cognitive learning outcomes is presented in the table below.

Table 9. Regression Analysis

Model Summary				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	0.401a	0,160	0,124	8.568

Based on Table 7, it is known that the R square value is 0.160 (16%). This shows that by using a regression model, the independent variable (SPS) has an influence on the dependent variable (cognitive learning outcomes) of 16%. While 84% is influenced by other variables, The results of the anova test are presented in the table below.

Tabel 10. Anova

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	322.823	1	322.823	4.397	0,047b
Residual	1688.537	23	73.415		
Total	2011.360	24			

Based on Table 8, the calculated F output value is 4.397 (significance 0.047 < 0.05), so it can be said that there is a significant correlation between SPS and students' cognitive learning outcomes. The results of simple linear regression are presented in Table 9 below.

Table 11. Simple Linear Regression Calculation Results

Coefficients a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	42.866	18.342		2.337	0,029
	Keterampilan Proses Sains	0,487	0,232	0,401	2.097	0,047

y= a + bx
y= 42,866 + 0,487*x

The coefficients of the simple regression equation above can be interpreted as a constant regression coefficient of 42.866, indicating that if the science process skill variable is zero or fixed, it will increase students' cognitive learning outcomes by 42.866 units. The coefficient value of the science process skill variable of 0.487 indicates that, if the science process skill variable increases by one unit, it will increase students' cognitive learning outcomes by 0.487 units, or 48.7%.

Discussion

Problem-Based Learning (PBL) consists of several authentic and meaningful problem presentation processes that are expected to facilitate students in carrying out the learning process as a whole (Hasbollah & Hasan, 2022). PBL focuses on authentic problems and allows students to build their knowledge, develop advanced skills, and be directly involved in research. PBL requires students to play an active role in learning activities that are not only centered on the teacher so that it can improve student learning outcomes on the learning material delivered by the teacher (Aidoo, 2023). PBL is considered capable of improving students' SPS and cognitive abilities because of its active nature and focus on problem-solving.

The findings indicate a significant difference in SPS and cognitive learning outcomes between the control and experimental groups, with the experimental group demonstrating higher performance. This difference highlights the positive effect of PBL implementation on students' SPS and cognitive learning outcomes. The results also show that the PBL model has a significant influence on these variables ($p = 0.038$). These findings are consistent with previous studies reporting that the PBL model positively impacts students' SPS and cognitive abilities (Anbiya & Khaldun, 2023; Putri, 2020; Liu & Pásztor, 2022).

According to Magaji (2021), this impact is because problem-based learning can help students develop problem-solving skills and abilities, where the problem-solving process can improve students' SPS. Students' SPS increase when students are asked to discuss in groups to solve problems given by the teacher (Idris et al., 2022; Doyan et al., 2021). This process stimulates critical and creative thinking in students, as well as developing problem-solving skills that are important in science. Therefore, the use of the PBL model can help students acquire better SPS (Sari et al., 2022).

In addition, problem-based learning affects students' critical thinking skills and cognitive learning outcomes (Liu & Pásztor, 2021). This finding is in line with previous research on the differences in average science learning outcomes between students who participate in PBL and those who do not (Safitri et al., 2023). It is also supported by other studies stating that PBL can improve conceptual understanding, the formation of social skills, the use of tools (psychomotor), and SPS (Amanda et al., 2022). So the application of SPS in the learning process is considered capable of producing optimal learning outcomes.

Problem-based learning (PBL) can improve SPS and cognitive learning outcomes because learning focuses on strengthening conceptual understanding through practical experience, improving problem-solving skills, encouraging active student participation, exploring information, increasing self-confidence, responsibility, cooperation and communication, and developing decision-making skills (Irwanto, 2023; Bororing et al., 2020). Previous research has shown that the use of the Problem-based Learning (PBL) learning model can help students hone problem-solving skills, improve understanding and knowledge, and encourage active involvement in the learning process (Sinusi et al., 2024). Other studies also show that problem-based learning models are used as an alternative because they can strengthen students' analytical, evaluative, and creative skills (Simanjuntak et al., 2021).

The Influence of SPS on Cognitive Learning Outcomes

SPS are the ability to perform physical or psychomotor actions such as observation, measurement, experimental design, and data analysis. This involves direct activity on the objects or materials being observed, thus emphasizing the practical aspect (Idris et al., 2023; Balmeo, 2022). There are four reasons why SPS are highly recommended for students to learn in everyday learning. First, with the continued development of science and technology, teachers cannot possibly teach all

concepts and facts to students. Second, students tend to understand complex and abstract concepts better if accompanied by concrete examples. Third, the discovery and development of science and technology are relative, not 100% absolute. Fourth, concept development cannot be separated from the development of attitudes and values in students.

This study demonstrates that the application of Science Process Skills (SPS) in the learning process can lead to optimal learning achievement (sig. = 0.047). These findings align with the studies of Mandasari et al. (2021) and Yusnidar et al. (2024), which revealed that SPS can significantly improve students' learning outcomes. The positive regression coefficient (b = 0.487) indicates a positive relationship between science process skills and learning outcomes. This means that the stronger a student's SPS, the higher their learning outcomes. This finding is consistent with the theory that SPS, such as observing, classifying, interpreting data, and communicating results, directly contribute to students' ability to understand scientific concepts deeply (Kwangmuang et al., 2021).

Furthermore, the beta value (standardized coefficient) of 0.401 indicates a moderate relationship between SPS and learning outcomes. This suggests that approximately 40.1% of the variation in learning outcomes can be explained by SPS, while the remaining variation is influenced by other factors such as learning motivation, cognitive ability, or a supportive learning environment.

The application of SPS in the learning process is therefore considered effective for achieving optimal learning outcomes. This is because SPS enables students to understand scientific concepts more comprehensively (Kwangmuang et al., 2021). SPS helps students construct knowledge through active engagement in acquiring scientific concepts (Higde & Aktamis, 2022). Moreover, SPS have a significant impact as they foster the development of students' intellectual abilities, practical skills, and social interactions (Alkhabra et al., 2023). Through SPS, students are trained to apply the steps of the scientific method, which encourages active thinking and independent knowledge construction. Consequently, applying SPS leads to a significant improvement in students' conceptual understanding and scientific learning outcomes.

Based on the results of this study, it can be seen that implementing intensive problem-based learning can have a major impact on student learning outcomes, both in terms of cognitive and psychomotor. The use of the PBL approach in the learning process can improve student learning achievement when compared to conventional methods. This is because, in PBL, students are invited to think critically and find and analyze problems according to everyday experiences and realities. SPS and students' cognitive learning outcomes are correlated; this can be seen from the strong relationship between SPS and students' cognitive learning outcomes when the problem-based learning (PBL) model is applied. Good SPS will produce good learning outcomes (Sari et al., 2022).

CONCLUSION AND RECOMMENDATION

Based on the results of the study, it can be concluded that the problem-based learning (PBL) learning model has significant effect on students' science process skill and cognitive learning outcomes at MAN 1 West Lombok. Students are directly involved in the scientific process. Through PBL stages such as identifying problems, conducting investigations, collecting and analyzing data, and drawing conclusions, teachers can help develop students' scientific skills. Students also learn theoretical concepts through real-world practice and actively construct knowledge, thereby improving their learning outcomes.

The effect of students' SPS on cognitive learning outcomes is significant. This indicates that these skills play a mediating role between PBL and cognitive learning outcomes. In other words, PBL enhances learning outcomes by improving students' SPS. Therefore, when students' SPS improve, they are better able to understand scientific concepts in depth, thereby contributing to higher learning outcomes.

The PBL has been proven effective in improving SPS and cognitive learning outcomes, so the implementation of PBL in science learning needs to be improved. Teachers can integrate SPS in every stage of PBL. For example, at the information gathering and investigation stage, students can be involved in observation, experimentation, and data analysis to further strengthen their SPS.

With the correlation between SPS and cognitive learning outcomes, teachers can focus more on developing SPS during the implementation of PBL. For example, through problem-based projects that emphasize observation, experimentation, and data analysis. The effect of SPS on cognitive outcomes is only 16%; further research is needed to explore other factors that can increase this influence. It is necessary to conduct periodic evaluations to monitor the development of student learning outcomes and SPS after the implementation of PBL. Furthermore, we suggest further research that explores other factors that can influence cognitive learning outcomes, both from internal aspects of students (such as motivation and interest) and external (such as the learning environment). Research can also expand the subject to other schools to strengthen the generalization of the results.

ACKNOWLEDGMENT

Thanks to the supervising teacher, Mrs. Suci Lestari, M. Pd as a teacher at MAN 1 West Lombok. Mr. H. Abdul Azis Faradi, M. Pd as the principal of MAN 1 West Lombok.

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