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Effectiveness of Problem-Based Learning Model on Cognitive Learning Outcomes and Science Self-Efficacy (SSE)

Marsha Hemalia Putri [1], Naili Inayah [2*], Aning Wida Yanti [3], Rizka Novia Rochmawati [4],

[1, 2, 3] UIN Sunan Ampel, Surabaya, Indonesia
[4] Sekolah Indonesia Jeddah (SIJ), Jeddah, Arab Saudi

* marshahemaliap25@gmail.com

Abstract

Students' cognitive learning outcomes and Science Self-Efficacy (SSE) are important factors influencing success in science learning. However, many students still demonstrate low confidence and limited understanding of Ecology, indicating the need for innovative learning models. This study aims to analyze the effectiveness of the Problem-Based Learning (PBL) model on cognitive learning outcomes and students' SSE in Ecology at the junior high school level. This study employed a quantitative approach with a one-group posttest-only design. The population consisted of seventh-grade students at Sekolah Indonesia Jeddah (SIJ), Saudi Arabia. Using simple random sampling, 22 students from class VII B were selected as the research sample. Data were collected using test and non-test instruments, namely an essay test to measure cognitive learning outcomes and a Science Self-Efficacy (SSE) questionnaire. Data were analyzed using descriptive statistics, the Shapiro–Wilk normality test as a prerequisite test, and a one-sample t-test for hypothesis testing. The results showed that the average score for students' cognitive learning outcomes was 89.59, and the average score for SSE was 84.86, with both distributions normal (Sig. > 0.05). The t-test results (Sig. = 0.000 < 0.05) showed that applying the PBL model significantly improved students' cognitive learning outcomes and SSE. The highest cognitive indicator was found in C6 (create), at 92.4%, followed by C5 (evaluate), at 73.4%. In addition, the most dominant dimension of SSE is Magnitude at 75%. The results of this study indicate that the PBL model is effective on students' cognitive learning outcomes and SSE in Ecology material.

Keywords: *Cognitive Learning Outcomes, Problem-Based Learning, Science Self-Efficacy*

Introduction

Education plays a strategic role in producing a high-quality, competitive generation. In the era of globalization, 21st-century education faces increasingly complex challenges amid rapid technological and information flows (Mulian et al., 2024). Students are required to master learning skills, digital literacy, and life and career skills that are relevant to the needs of the times (Virmayanti et al., 2023). In addition, students must also be able to develop 21st-century skills known as the 4C, namely critical thinking, creativity, communication, collaboration, and problem-solving skills (Partono et al., 2021). To improve the quality of education, every teacher is required to innovate in the learning process to enhance students' understanding and ability to grasp the material taught (Rohmawati et al., 2025).

The subject that requires innovation in the application of learning is Natural Sciences. Natural Sciences is a branch of science that studies nature and the phenomena that occur in it (Pujilestari et al., 2022). In addition, science learning serves as a foundation for mastering

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various other disciplines and becomes the basis for the development and application of science and technology (Putri et al., 2025). The science learning process emphasizes the observation of real phenomena that are closely related to daily life. Therefore, science learning needs to be designed to provide students with direct experience, enabling them to develop scientific competence optimally. As an effort to achieve optimal mastery of science concepts, a learning pattern is needed that focuses on increasing mastery of concepts in the science learning process (Sudjana, 2016). Mastery of science concepts in the learning process can be reflected in the Exit in the form of learning outcomes. Learning outcomes are categorized into three domains, namely cognitive, affective, and psychomotor (Hapsari et al., 2023).

Learning outcomes in the cognitive realm are behavioral changes that occur in the cognitive domain, covering various abilities that cause behavioral changes in the cognitive domain, including several levels. Learning outcomes in the cognitive realm are classified into six mutually continuous levels. The first level, in the form of C1 (Remembering), is the ability to regain knowledge from memories. C2 (Understanding) is the formation of an understanding of various materials. The C3 (Applying) level refers to students' ability to apply knowledge to determine, perform, and complete specific tasks or procedures. At the C4 level (Analyzing), students are invited to study, compare, and test a real problem. C5 (Evaluating) requires students to assess and critique a test or product against a given standard. In C6 (Create), students are encouraged to produce new products sourced from previous learning experiences (Gunawan & Palupi, 2016). Improved cognitive learning outcomes can be influenced by a variety of factors, including internal factors.

One of them is the ability of students to manage the learning process, especially confidence in their ability to achieve learning goals (Athia et al., 2024). The belief reflects a student's confidence in their ability to perform the expected actions in a given situation, resulting in positive outcomes, known as Self-efficacy. Self-efficacy is an individual's belief in their ability to plan and execute the actions necessary to achieve a specific goal (Blom et al., 2021). In Science learning, students' self-confidence in their abilities is also needed in completing particular tasks in the field of Science called Science Self-Efficacy (SSE) (Liu et al., 2024). Students with higher levels of SSE are better able to face difficulties, show stronger motivation, and participate more actively in the science learning process. Thus, SSE plays an essential role in improving the learning success of students in the field of Science (Lin, 2021).

Science Self-Efficacy (SSE) can help students build confidence so they do not easily feel incapable of participating in learning activities. SSE can also encourage students to set clear learning goals, so that the learning process is not just a formal routine, but is directed towards achieving goals that the students themselves have set (Taneo & Koro, 2022). SSE can be seen through three dimensions Self-efficacy submitted by (Bandura, 1997). The dimension Magnitude, students' self-confidence as reflected in their ability to solve problems at various levels of difficulty. Next, the dimension Strength, which reflects students' consistency and perseverance in learning to achieve success. Meanwhile, the dimensions generally demonstrate students' ability to apply knowledge appropriately across various learning topics.

Real problems arise when students struggle to connect science concepts to everyday phenomena. This is supported by the results of pre-research on science learning in grade VII of junior high school at Sekolah Indonesia Jeddah (SIJ), Saudi Arabia. The results show that students' understanding of the material is still relatively low, as evidenced by a cognitive diagnostic test in the Ecology material with an average student score of 59, which is classified as low and has not reached the KKM score of 75. This shows that students' initial knowledge remains limited, affecting their depth of understanding of learning concepts. In addition, students tend to be less confident in expressing opinions and asking questions during the learning process. Teachers' learning processes tend to involve students less actively in identifying contextually relevant problems in their daily lives. Essential material, such as Ecology, not only emphasizes understanding of concepts and theories, but also fosters students' concern for the environment (Rohmawati et al., 2025).

The Ecology material invites students to understand the structure and function of ecosystems that involve the value of concern for the environment, awareness of dynamics, and responsibility for environmental sustainability (Musyaropah, 2023). Ecology Learning emphasizes improving students' cognitive abilities and creativity in understanding the concept of Ecology in depth, as well as finding solutions to increasingly complex environmental problems (Hardiansyah & Wahdian, 2023). Learning innovations that present a real problem as a trigger for learning include Problem-Based Learning (PBL). This model focuses on solving real problems that are relevant to students' lives to encourage them to think critically and creatively in finding solutions (Lestari & Rahmandani, 2023). The PBL model consists of five critical stages, namely: (1) orienting students to problems, (2) organizing students to learn, (3) guiding individual and group investigations, (4) developing and presenting the results of the work, and (5) analyzing and evaluating the problem-solving process. Through these stages, students are trained to play an active role in the learning process and build knowledge independently (Pagampa et al., 2023).

Thus, the application of PBL model can provide opportunities for students to find alternative solutions to problems faced in daily life (Safithri et al., 2021; Safira & Handayani, 2025). The application of the PBL model was more effective than conventional learning in science classes for seventh-grade junior high school students, with an average score of 79.94% and a learning completeness rate of 79.41% (Sutrisna & Sasmita, 2022). The findings confirm that PBL model can improve science learning outcomes while encouraging active student involvement and motivation. In addition, Wardah and Sani (2025) reported that the implementation of PBL model significantly improved students' self-efficacy in biodiversity material for seventh-grade junior high school students, with an effect size of 1.67 and a significance level of 0.00 < 0.05, indicating a high category (Wardah & Sani, 2025). Research on the implementation of the PBL model has been widely conducted in science education. However, studies examining the effectiveness of PBL model on students' SSE and cognitive learning outcomes remain limited. In particular, research focusing on these two aspects simultaneously in Ecology learning at the junior high school level is still scarce.

This condition indicates the need for further research to find out the extent to which the application of PBL model can affect both aspects. Therefore, this study aims to analyze the effectiveness of the PBL model on students' cognitive learning outcomes and SSE. The novelty of this study lies in the integration of cognitive learning outcomes and Science Self-Efficacy (SSE) within a single framework for evaluating the effectiveness of the Problem-Based Learning (PBL) model, which have often been examined separately in previous studies. This research not only assesses improvements in students' conceptual understanding but also explores how PBL simultaneously fosters students' confidence in their scientific abilities when solving contextual problems. Furthermore, the study contributes by examining the relationship between SSE enhancement and cognitive achievement as a comprehensive indicator of learning success, offering a more holistic perspective on PBL effectiveness compared to prior research that typically focuses on only one aspect.

Method

This study uses a quantitative approach, employing a Quasi-Experimental Design and a one-group posttest-only research design. This method is used to determine the effectiveness of the Problem-Based Learning (PBL) model on students' cognitive learning outcomes and SSE, by involving one experimental class that is given treatment in the form of the application of the Problem-Based Learning model (PBL). The study population comprised grade VII Junior High School students at Sekolah Indonesia Jeddah (SIJ) in Saudi Arabia. The sampling technique was simple random sampling, yielding a sample of 22 students in class VII B, which was normally distributed. The independent variables (X) in this study are the PBL model, while the dependent variables (Y_1) are students' cognitive learning outcomes, and (Y_2) is SSE. The following is an overview of the research design in Table 1.

Table 1. *Research design*

Group	Treatment	Post-test
1	**X**	Y1
		Y2
	Time ➞	

Information: X: Type Problem-Based Learning (PBL), Y_1: Students' cognitive learning outcomes, and Y_2: Science Self-Efficacy (SSE). The data collection techniques in this study are in the form of test and non-test instruments. The test instrument was carried out to measure students' cognitive learning outcomes related to the Ecology material. The cognitive learning outcome test consists of description questions adjusted to the cognitive level indicated by the operational verbs in Learning Outcomes and Learning Objectives. Thus, the cognitive learning outcome test is designed in accordance with the minimum cognitive level standards in Learning Outcomes, namely C2 (Understanding) to C6 (Creating). The following is a grid of student cognitive learning outcomes tests presented in Table 2.

Table 2. *Cognitive learning outcomes grid*

Learning Objectives	Question Indicator	Cognitive Level	Question Number
Correctly categorize abiotic and biotic factors that affect the environment for living things.	Presented with the problem, students can identify the biotic and abiotic factors it contains.	C3	1
	Presented with a follow-up statement, students can analyze the relationship between the two.	C4	2
Analyze the precise influence of the environment on an organism.	When presented with questions about abiotic factors, students can predict environmental conditions if one of the abiotic components is absent from the ecosystem.	C5	3
Analyze the interactions among the components of an ecosystem appropriately.	Presented with images and statements about food chains in desert ecosystems, students can analyze the interactions among ecosystem components.	C4	4
Correctly depicting the food chain.	Presented with a follow-up statement, students were able to describe the food chain contained in the food webs.	C6	5
Classify the role of each individual in a food chain appropriately.	Presented with questions about the roles of individuals in these food webs, students were able to classify each individual's role in the food chain.	C2	6

On non-test instruments in the form of questionnaires to measure SSE of students, which was compiled by adapting a questionnaire developed by Harpison (2025). The Questionnaire Science Self-Efficacy (SSE), adapted for the Secondary School level, has been standardized and contains several dimensional indicators of Self-efficacy according to Bandura (1997):

Magnitude, Strength, and Generality. The questionnaire comprised 30 questions, 15 positive and 15 negative. The following presents the SSE questionnaire grid in Table 3.

Table 3. *Science Self-Efficacy (SSE) questionnaire grid*

Dimension	Indicators	Example Statement	Item Number	
			Positive	Negative
Magnitude/ Level	Confidence in taking action to achieve results and overcome obstacles	I always do the Science assignments given by the teacher	1, 4, 5, 6,7, 11, 16	2, 3, 8, 9, 10, 14
Strength	Commitment to complete academic tasks well and not give up easily	I tried another way if I didn't find the answer to the Science question	13, 15, 17,19, 22	12,18, 20, 30
Generality	Looking at the situation positively and making it an experience to boost confidence	I didn't give up, even though Science was difficult	24, 25, 26, 28	21, 23, 27, 29

Technical data analysis involves descriptive tests of students' cognitive learning outcomes and SSE questionnaire data to determine the categories of cognitive learning outcomes and SSE among students. SSE categorization criteria are presented in Table 4.

Table 4. *Science Self-Efficacy (SSE) Categorization*

Guidelines	Criteria
$90 \leq x \leq 100$	Very High
$80 \leq x < 90$	High
$70 \leq x < 80$	Medium
$50 \leq x < 70$	Low
$0 \leq x < 50$	Very Low

The following analysis technique uses SPSS Version 27 to conduct data analysis through three stages of statistical testing, namely (1) statistical descriptive analysis test, (1) prerequisite test (Shapiro-Wilk normality test), and (3) hypothesis test through One Sample T-test. Thus, the hypothesis in this study is that H_0 = the PBL Model is not effective in improving students' cognitive learning outcomes and SSE. In contrast, the H_1 = the PBL Model is efficacious in enhancing students' cognitive learning outcomes and SSE. Decision-making is based on significance values, with the provision that if sig < 0.05, then H_0 is rejected, indicating that the PBL model is efficacious in improving students' cognitive learning outcomes and SSE.

Results

Statistical Descriptive Analysis

The results of the initial description include post-test data on students' cognitive learning outcomes and Science Self-Efficacy (SSE) to identify patterns of student achievement following treatment through a Problem-Based Learning (PBL) model. The following is presented post-test data on students' cognitive learning outcomes in Table 5.

Table 5. *Students' Cognitive Learning Outcomes*

Guidelines	Frequency	Percentage (%)
$90 \leq x \leq 100$	13	59
$80 \leq x < 90$	8	36
$70 \leq x < 80$	1	5

Based on the data in Table 5, most students achieved high cognitive learning outcomes. A majority of students (59%) scored in the 90–100 range, while 36% obtained scores between 80 and 89, indicating good achievement. Only 5% of students scored between 70 and 79. These results provide an overview of the extent to which learning develops students' thinking skills at the cognitive level, as determined by operational verbs in Learning Outcomes and Learning Objectives. The results are shown in Table 6.

Table 6. *Average Analysis of Cognitive Level*

Level	Maximum Score	Correspondence	Percentage (%)
C2	10	7,65	30,6
C3	15	13,95	55,8
C4	15	13,88	55,5
C5	20	18,35	73,4
C6	25	23,10	92,4

Based on the analysis in Table 6, the average score increases with students' cognitive level.The C2 cognitive level has the lowest achievement at 30.6%, while the C6 cognitive level has the highest at 92.4%.This indicates that students' high-level thinking skills are especially strong in analysis and evaluation.Furthermore, the results for SSE among students are presented in Table 7.

Table 7. *SSE Students*

Guidelines	Criteria	Frequency	Percentage (%)
84 < X ≤ 102	High	15	68
66 < X ≤ 83	Medium	7	32

Based on data from Table 7, students' SSE showed that most were in the High category (15 students, 60%), followed by seven students (38%) in the Medium category. Furthermore, the data SSE of students is analyzed across three dimensions: Magnitude, Strength, and Generality. The results of the categories in the three dimensions are presented in Table 8.

Table 8*. Recap per dimension indicator SSE*

Aspects	Dimension		
	Magnitude	Strength	Generality
Average Score Per Dimension (%)	75%	68%	73%
Categories By Interval	Medium	Medium	Medium

Table 8 shows that the average score per indicator for 22 students was 72%, indicating that students' SSE after applying the PBL model was in the Medium category. Next, a descriptive test was carried out on the two variables presented in Table 9.

Table 9. *Descriptive test of cognitive learning outcomes and SSE*

	Mean	Standard deviation	Minimum	Maximum
Students' cognitive learning outcomes	89,59	7,242	74	100
Science Self-Efficacy (SSE)	84,86	8,184	66	102

Based on the descriptive test in Table 9, the average student cognitive learning outcome was 89.59, with a standard deviation of 7.242, indicating that students' achievement is at a similar and consistent level of concept mastery. Similarly, the average SSE was 84.86, with a standard deviation of 8.184, indicating that students' self-confidence in science was in the good category and that the data were homogeneous. After the descriptive analysis, an inferential statistical analysis was conducted, including a normality test and a t-test.

Inferential Statistical Analysis

Inferential statistical analysis test consisting of a normality test and a t-test. The normality test is used to ensure that the research data are typically distributed, a prerequisite for further analysis. Normality test using the test Shapiro-Wilk, which is used to test data with a relatively small sample count (n < 30). The results of this test are presented in Table 10.

Table 10. *Normality test*

Statistical Test	Post-test Cognitive learning outcomes	Science Self-Efficacy (SSE)
Statistics	0,945	0,979
Sig.	0,256	0,900
Conclusion	Sig > 0.05 or normal distribution	

The normality test in Table 10 indicates that the Shapiro-Wilk test with a sample of 22 students yielded a significance score (Sig.) of 0.256 for cognitive learning outcomes and 0.900 for SSE. Both values exceed the 0.05 significance level, so the data for both variables are normally distributed. Thus, the assumption of normality is met, allowing data analysis to continue using parametric statistical tests. Furthermore, hypothesis testing was carried out using the one-sample t-test in SPSS version 27. The results of the study are shown in Table 11 below.

Table 11. *Hypothesis test*

Statistical test	Post-test Cognitive learning outcomes	Science Self-Efficacy (SSE)
Mean	89.59	84,86
α	0,05	0,05
Sig. (2 Tailed)	0,000	0,000
Conclusion	Sig. (2 tailed) < α or 0.001 < 0.05	

Based on the statistical test in Table 11, a significance value (Sig. 2-tailed) of < 0.000 was obtained for the cognitive learning outcome variable. In addition, the significance value (Sig. 2-tailed) was < 0.000 for the SSE variable. This value is smaller than the specified significance level, which is α = 0.05. Thus, the null hypothesis (H_0) is rejected. The alternative hypothesis (H_1) is accepted, indicating a significant difference between the students' test results and the reference score, suggesting that the PBL model has a substantial impact on students' cognitive learning outcomes and SSE.

Discussion

Students' cognitive learning outcomes in applying the Problem-Based Learning (PBL) model were assessed using post-test scores after the learning intervention. The application of the PBL model has been proven to significantly improve students' cognitive learning outcomes, as evidenced by the average post-test score of 89.59, which falls within the high category, and a t-test significance value of α < 0.000. Statistically, these results confirm that the PBL model is effective for students' cognitive learning outcomes. Based on the score distribution, scores ranged from 90–100, while 36% scored between 80 and 89, indicating good achievement. Only 5% of students scored between 70 and 79.

Based on the study's results, PBL model is considered capable of improving students' cognitive learning outcomes in Ecology materials. The practical application of PBL model can affect overall cognitive level in this study, which aligns with the minimum standard in Learning Outcomes, namely C2 (Understanding). Thus, the cognitive learning outcome test is designed in accordance with the minimum cognitive level standards in Learning Outcomes, namely C2 (Understanding) to C6 (Create). The results of the cognitive learning test showed that the most dominant improvement in student abilities was from C3 (Apply) to C6 (Create), with the highest achievement at C6 (Create). Meanwhile, the ability at the C2 level (Understanding) showed a less significant increase in the application of this learning model.

At the cognitive level, C6 (Create) can be achieved through the application of the PBL model, which emphasizes the last syntax: Analyzing and Evaluating Problem-Solving Process. The syntax focuses on solving contextual problems that are relevant to real life, thus training students to put forward ideas in search of solutions. Through this process, students can formulate and create new solutions to problems posed during learning (Ilmi & Lagiono, 2019).

The second-highest cognitive level, namely C5 (Evaluating), in the application of the PBL model can be achieved through the syntax of developing and presenting the work. In this syntax, the learning process is carried out through discussion. Students are encouraged to solve problems by coming up with ideas and solutions (Mulian et al., 2024). This kind of learning process can also develop students' evaluative abilities, as they are trained to make decisions, formulate solutions, and come up with ideas based on problems found in the school environment (Pramesti et al., 2022).

Improving cognitive learning outcomes depends not only on students' intellectual abilities but also on internal and external factors. Internal factors include physiological aspects, intelligence, talents, interests, self-perception, motivation, and attitude (Taneo & Koro, 2022). Meanwhile, external factors are sourced from outside the student, such as family, school, and social environment (Firdaus et al., 2023). This shows that students' self-confidence plays an essential role in the science learning process. Students with SSE are more confident in exploring and solving scientific problems. Science Self-Efficacy (SSE) students show that as many as 68% are in the High category, with a t-test Significance value (Sig. 2-tailed) of < 0.000. Value SSE Students are obtained from three dimensions of Self-efficacy submitted by (Bandura, 1997), i.e. the Magnitude by 75%, Strength by 68%, and Generality by 73%. Visualization of the results for each of these aspects is presented in Figure 1.

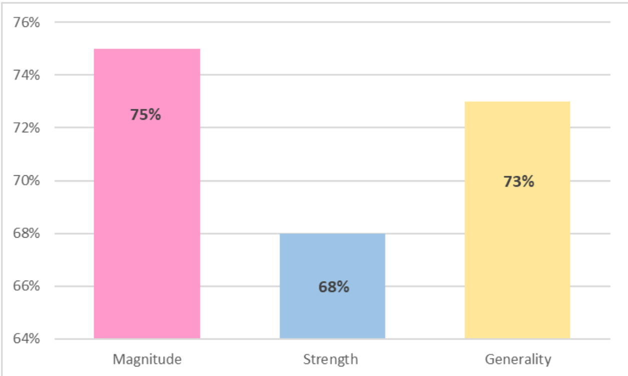

Figure 1. *Graph of students' SSE dimensions*

On the dimensions, Magnitude reflects students' ability to solve easy problems to complex problems, or to demand high-level thinking skills (Bandura, 1997). The learning process through models, PBL model, can support the Magnitude dimension by helping students progress through the syntax: Organizing Students for Learning. This syntax focuses on analyzing issues, helping students build self-confidence and perseverance in completing learning tasks (Reflina, 2018). On the dimensions, Strength reflects the student's level of confidence in completing the task well and consistently (Liu et al., 2024). It also shows that students try to complete tasks optimally. This dimension can be supported through the syntax: Guiding individual and group investigations. This syntax provides students with an opportunity to search for and gather relevant information to solve the problems they face. The exploration process can build self-confidence in completing tasks despite facing information limitations (Blom et al., 2021).

On the dimension of Generality, it can be seen from students' ability to take advantage of learning experiences to grow and become motivated in the next learning. Students with high Self-efficacy in the Generality dimension tend to actively evaluate understanding and learning outcomes as a form of self-regulation to improve the learning process, and tend to use various strategies to complete complex tasks (Boden et al., 2023). Dimension Generality can be supported through the learning process by syntax: Developing and presenting the results of students' work. The syntax provides students with an opportunity to present and construct concepts in Ecology. Such activities can strengthen the dimension Generality, because they involve students' ability to overcome challenges and apply knowledge of a broader context (Reflina, 2018).

Based on the findings, it can be concluded that the application of the PBL model effectively contributes to student learning outcomes in the cognitive domain and in SSE. During the research, students' learning of Ecology material through a PBL model made them more independent and active during learning. This aligns with the primary purpose of the PBL model: to help students develop fundamental knowledge, problem-solving skills, independent learning, collaboration, and intrinsic motivation (Purwanto et al., 2020). In line with the constructivist paradigm, PBL model can encourage students to build their own knowledge through meaningful learning experiences actively (Nurtanto & Fawaid, 2015).

In a model application of PBL model, students engage directly in authentic activities that reflect real-world situations, enabling them to construct and apply knowledge contextually. The implementing PBL model can foster meaningful learning and improve students' critical thinking skills through contextual problem-solving activities (Safithri et al., 2021). The applying the PBL model significantly improves student learning outcomes in Ecology (Keden et al., 2025),. Thus, the effectiveness of the PBL model in this research not only lies in its problem-based characteristics, but also in contextual learning of Ecology material in science learning, so that it is proven to be able to provide a meaningful learning experience, improve student learning outcomes in the cognitive realm, and strengthen SSE of students.

Conclusion

Based on the research objectives and findings, the Problem-Based Learning (PBL) model is effective in improving students' cognitive learning outcomes and Science Self-Efficacy (SSE) in Ecology learning. Students achieved high average cognitive scores of 89.59 and strong SSE scores of 84.86. A one-sample t-test indicated a significant effect of the model on both variables (Sig. < 0.05). The highest cognitive achievement was observed at the C6 (Create) level. In terms of SSE, the Magnitude dimension was the strongest aspect, indicating students' confidence in completing tasks with varying levels of difficulty. These findings suggest that the PBL model supports meaningful science learning, particularly in Ecology, where problem-solving and critical thinking skills are required. However, this study has several limitations, including the use of a one-group posttest-only design and a relatively small sample size. Therefore, future research is recommended to employ more rigorous experimental designs with larger samples and to explore the effectiveness of PBL model in other science topics or educational contexts.

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